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THE EFFECT OF TIME AND NUMBER OF APPLICATIONS OF CHLORMEQUAT AND ANCYMIDOL ON THE GROWTH AND FLOWERING OF SEED GERANIUMS

Pelargonium X *hortorum* Bailey

presented by

Ricardo Motta Miranda

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THE EFFECT OF TIME AND NUMBER OF APPLICATIONS OF CHLORMEQUAT AND ANCYMIDOL ON THE GROWTH AND FLOWERING OF SEED GERANIUMS
PELARGONIUM X *HORTORUM* BAILEY

By

Ricardo Motta Miranda

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ABSTRACT

THE EFFECT OF TIME AND NUMBER OF APPLICATIONS OF CHLORMEQUAT AND ANCYMIDOL ON THE GROWTH AND FLOWERING OF SEED GERANIUMS

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The growth retardants Chlormequat (CCC) and Ancymidol (A-Rest) are used on seed geraniums not only to control growth, but also to hasten flowering. This research was conducted to determine the effect of repeated applications and time of application of CCC (1500 ppm) and A-Rest (200 ppm) as sprays on the growth and flowering of the seed geranium cultivars Sprinter Scarlet and Sprinter Salmon. Observations were made on microtome sections of the apical meristem of Sprinter Scarlet plants, to study the effect of the time of application treatments on flower initiation.

Plants treated at any time and with any number of applications flowered significantly earlier than control plants, although no significant difference was observed among the growth retardant treatments. As the number of applications increased or as applications got later, growth control tended to increase on all growth

parameters measured. Flower initiation occurred one to two weeks earlier than the control on all growth retardant treated plants, suggesting that growth retardants induce early flower initiation rather than accelerate the flower sprout development.

In order to achieve the ideal overall response, the best time of application is 35 days after sowing. The double application (35 + 42 days) can be done when a sharper growth control is desired. Excessive growth control was observed with more than two applications.

The results led to the hypothesis that the mode of action of growth retardants to induce early flowering is not the same mode of action to control plant growth on seed geraniums.

DEDICATION

To Thereza, Dilza, Su and Nina

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Garden geraniums are produced by sixty percent of U.S. greenhouse operations. According to the Crop Reporting Board's 1978 Statistics for Floriculture Crops, total geranium production as pot plants in the U.S. is as follows:

	1976	1977
Producers (number)	2,324	2,525
Production area (1,000 sq.ft.)	15,619	15,900
Pots sold (1,000 pots)	47,992	45,936
Percent of sale at wholesale (%)	78	76
Wholesale price (dollars)	.67	.67
Value of sales at wholesale (1,000 dollars)	32,096	30,816

Carlson (1978) stated that the above figures fail to include seedling geranium production, and that total geranium production in the U.S. for 1977 represented approximately 250 million plants, of which 60 million are produced from seeds.

No other flower has shown a greater rate of increase in dollar value to commercial floriculture and better performance for purchasers during the last 25 years (Voigt, 1971).

It has been estimated that, together, seed and cutting geraniums are fast approaching $100 million a year from growers of all states, led by (in order) Massachusetts, Michigan, Ohio and New York (Reilly, 1977).

Much of this increase in geranium production has occurred because of the shift from cutting propagation to seed. Since the introduction of the first true breeding commercial seed cultivar, Nittany Lion Red, released by Penn State in 1964, extensive geranium breeding has been carried out resulting in numerous cultivars being released from several commercial seed companies.

Compared with cutting production, seed geraniums have superior attributes, such as: (1) Lower cost; the grower has less overhead involved in the propagation area because it requires less space to start plants from seeds than from stock plants. (2) Predictability; precise schedule allows the grower to plan the operations. (3) Plant quality; the plants are vigorous, well branched and free of disease when seeded. (4) Colors; many flower colors are now available. (5) Germination percentage; very high for most cultivars (Adams, 1978). Regardless of these attributes, seed geraniums have a few limitations. The more important are: (1) Germination temperatures; which must be very specific.

(2) Flowers; which are single and have a tendency to prematurely drop petals more readily than cutting geraniums. (3) Time to flower; which takes longer with seed compared with vegetative propagated geraniums (Adams, 1978 and Larson, 1968).

Among the seed geranium limitations, flowering time is probably the most important. Plant size is also an important factor for shipping purposes. Research has been conducted in order to keep the plants short and decrease flowering time. These aspects have been a priority in breeding programs, but most of the research has concentrated on cultural and environmental factors. The most important factors affecting seed geranium growth and flowering are: temperature, light and growth regulators (Larson, 1968).

Growth retardants to keep plants short and decrease flowering time have been widely used by geranium growers. Most information available concerns types of growth retardants, concentrations and application systems. There is, however, a lack of information regarding time of application and number of applications of growth retardants on seed geraniums. This information is useful because time and number of applications affect plant response to growth retardants and consequently production costs.

The major objective of this work was to determine the effect of time of application and number of applications of growth retardants on seed geranium growth and flowering. The following parameters were determined and compared for each treatment: days to flower, floret size, number of florets, vegetative height, total height, number of flower stalks, number of breaks, leaf diameter and fresh weight. The effect of the treatments on flower initiation was also determined by observing the plants' apical meristem development at regular intervals.

LITERATURE REVIEW

Plant Systematics

Pelargonium x *hortorum* Bailey is the most important species for commercial geranium production. This species is sometimes erroneously referred to as *Pelargonium zonale* L. According to Craig (1971) the latter binomial should not be used to designate cultivars of the garden geranium. The hybrid species *P.* x *hortorum* has resulted from the intercrossing of species within the sub-genus *Ciconium*. Although there are some controversy among authors, the major contributing species, according to Craig (1971), are: *P. zonale* L., *P. inquinans* L., *P. hybridium* L., *P. frutetorum* Dyer and *P. scandens* Ehrhart.

Genetics and Breeding

Pelargonium x *hortorum* Bailey is reported as 2N = 9,17,18,35 and 36, and inheritance of plant habit is conditioned by one major gene acting with incomplete dominance (Craig, 1971 and Ewart, 1978). For genetic purposes geraniums have been classified as dwarf, semidwarf and tall.

Distinct breeding programs have been established for asexually propagated cultivars and seed propagated cultivars. Cultivars propagated from cuttings may be either diploids or tetraploids. Most of the commercial cutting geraniums are tetraploid, 2N = 36 (Craig, 1971).

The commercial seed propagated cultivars are mostly F_1 hybrids and are genetically uniform. Geranium seedling are thus equivalent to culture indexed cuttings as a source of propagative material. All the commercial available seed cultivars are diploid, 2N = 18 (Craig, 1971).

Since the introduction of Nittany Lion Red, earliness of flowering and plant height have been two of the major selection criteria used for seed geranium breeding lines. Other criteria for seed cultivar evaluation have been: leaf size; shape and placement; leaf zonation; flower color, size and type; seed germination; pest resistance; general vigor; tolerance to garden conditions; seed production; pollen production and response to the environmental factors (Craig, 1971).

Seedling Cultivars

After the cultivar Nittany Lion Red was introduced by Penn State, many seed companies developed their own cultivars with specific desirable characteristics. The major cultivars or series of cultivars and their average number of weeks from sowing to first flower are listed below, in order of introduction:

Name	Seed Company	Number of cultivars	Weeks to 1st flower
Carefree F_1 Hybrids	Pan American	13	16 to 19
New Era F_1 Hybrids	Harris	10	18
Sprinter F_1 Hybrids	Goldsmith	4	15 to 17
Cherie F_1 Hybrid	Goldsmith	1	16
Firecracker F_1	Pan American	1	15
Scarlet Flash F_1	Pan American	1	16
Show Girl F_1	Goldsmith	1	16
New Early Hybrids	Harris	4	15 to 17
Sooner F_1 Hybrids	Denholm	3	15 to 17
Ringo F_1 Hybrids	Sluis and Groot	3	15 to 17

(Adapted from Adams, 1978)

Even though the genetic constitution of the hybrid is of prime importance, significant variation in the number of days to first flower, growth habit and other characteristics can be accounted for by cultural and environmental factors.

Cultural and Environmental Factors

1) Pinching - Lindstron (1967) did not observe any difference in flowering time due to pinching. Wilkins and Widmer (1968), Craig and Walker (1963) and White (1970) reported at least 24 days increase in flowering

time when plants were pinched, as well as a reduction in plant size.

2) Sowing date - Craig (1968), Wilkins and Widmer (1968) and Konjoian and Tayama (1978) reported that crop time steadily decreased as propagation got later. This is likely to be the result of increased light intensity in the latter part of winter and into spring (Konjoian and Tayama, 1978).

3) Fertility - White and Wick (1978) reported a significant increase in height and fresh weight but a significant reduction in flowering time as fertility level increased, for all cultivars tested.

4) Water - White (1970) reported that water stress was more effective than Chlormequat in reducing height, but delayed time to flower. Fresh weight, number of buds and number of branches were reduced as the result of water stress. White also observed that the height control by Chlormequat was more evident in less watered plants. This observation disagreed with Plaut *et al.* (1964) who reported that the Chlormequat effect was more apparent in wet treatments for bean plants.

5) Temperature - Temperature is known to be the primary factor promoting flowering of some cultivars of cutting geraniums (Hackett *et al.*, 1974; Hackett and Kister, 1974 and Nilsen, 1975). Post (1949) stated that

Pelargonium x *hortorum* delay flower buds at temperatures below 15.5°C (60°F). Hackett and Kister (1974) reported that the flower response to low temperatures varies within cultivars. Mastarlez (1967) reported that as night temperature increased, the growth rate of clonal propagated geraniums increased resulting in slightly earlier flowering.

Carpenter and Carlson (1970) working with seed geraniums, reported that in growth chambers with 75°F day temperature and 70, 60 and 50°F night temperature, the earliest flowering was at 70°F with five and 15 days delay at 60°F and 50°F, respectively. In the same work the plant height decreased as night temperatures increased.

Stinson (1971), concluded that the optimum night temperature for geranium growth and flowering is from 60 to 62°F, and day temperature from 65 to 70°F.

Konjoian and Tayama (1978) reported that days to flower was the factor most affected by night temperature. From 55 to 65°F, each 5°F increase advanced flowering by nine to ten days.

6) Light - Post (1942) classified geraniums as a photoperiod neutral plant in regard to flower induction. This has been confirmed for both asexually propagated geraniums (Rerko, 1956) and for seed propagated geraniums (Craig, 1960).

Craig and Walker (1961) reported that a reduction in light intensity resulted in plants which flowered later and were taller than controls. Craig and Walker (1963) suggested that the production of the hypothetical substance which controls flower induction is apparently independent of number of days and length of photoperiod, but dependent upon temperature and solar energy. They also reported that solar energy may be used to regulate the time of the flowering of seed geraniums.

Larson (1968) reported little difference in time required for flowering of seed geraniums, when photoperiod treatments were compared. However Larson observed that plants grown under a twelve or nine hour day length were generally shorter than plants grown under a sixteen hour day length. Regarding the response to solar energy, he came out with the following summary:

Characteristics	Low Solar Energy	High Solar Energy
Flower initiation	Delayed	Accelerated
Vegetative growth	Long period	Short period
Plant height	Tall	Short

He also pointed out that it is very likely that geranium varieties will eventually be placed in response groups, based on response to solar energy.

Carpenter and Rodriquez (1971) reported that seedling geraniums given supplementary lighting, from fluorescent lamps, for six to ten weeks flowered uniformly, and 24 to 55 days earlier with two to six fewer nodes than those receiving no supplementary light or illuminated for a shorter time. Similar results were obtained by Norton (1973), who reported that illumination with high pressure sodium and metal-halide lamps resulted in three weeks earlier flowering than control plants.

Carpenter (1974), observed that supplementary light (Lucalox $10W/ft^2$) after transplanting induced earlier flowering than lighting before transplanting, and both were better than using only seasonal day light. Armitage *et al.* (1978) also reported a difference of 26 days in flowering time when high pressure sodium lighting was used. Konjoian and Tayama (1978) also observed earlier flowering due to light, when incandescent bulbs were used.

7) Growth Retardants - The mode of action of growth retardants on plants is not yet totally explained. Lang (1970) reported that (2-chloroethyl)trimethylammonium chloride, (Chlormequat), (CCC); tributyl(2,4-dichlorobenzyl)phosphonium chloride, (Phosphon), (CBBP) and N,N,N-2-tetramethyl-5-(1-methylethyl)4-1-piperidinylcarbonyl)oxy-benzenaminium chloride, (Ammo-1618), (ACPA), inhibit synthesis of gibberellin at the point of geranylgeranoil conversion to kaurene. X-cyclopropyl-x-(4-methoxyphenyl)-5-pyrimidine-methanol,

(Ancymidol), (A-Rest) also inhibits synthesis of gibberl-lin, but by acting on the oxidation steps between kaurene and the ring contraction to produce the gibbane skeleton of gibberellin. Since those growth retardants are inhibitors of gibberellin biogenesis, they cause a decrease of the endogenous gibberellin level thus a retardation of vegetative growth, and in some cases early flowering.

Holcomb and White (1968) reported the effect of Chlormequat in controlling height and flowering time in seed geraniums. They found out that some cultivars drenched with 2,400 ppm Chlormequat reached anthesis five to seven days earlier than the control. Lower fresh weight and number of nodes were also observed on treated plants.

Semeniuk and Taylor (1970), found that combinations of Chlormequat; [3-methyl-5-2-cyclohexen-1-yl)-cis-trans-2, 4-pentadienoic acid], (abscisic acid), (ABA); Phosphon and 2-chloroethylphosphonic acid, (Ethrel), (CEPA) applied 72 days after sowing did not decrease time to flower, but ABA and CEPA delayed flowering. They also observed that Chlormequat suppressed the vegetative growth, shortened the internodes and increased the number of basal shoots and number of flowers of treated plants.

White (1970) conducted an experiment with three concentrations of Chlormequat and five application days; 31, 36, 41, 46 and 51 days after sowing. He observed that the earliest application resulted in flowering eight to 16 days earlier than the control. No significant difference in time to flower was observed among Chlormequat concentrations. Plant height did not seem to follow any trend within Chlormequat application time or Chlormequat concentration, but all treated plants were significantly shorter than the control. Larson (1968) reported that earlier application of Chlormequat severely checked plant growth, while a delayed application was less effective.

Payne (1969), White (1970) and Carlson (1976) reported varietal differences in response to Chlormequat treatments. Carpenter and Carlson (1970) reported that 2,3,5-triiodobenzoic acid, (TIBA) caused earlier flowering and lower height than control. Similar effects were reported for Chlormequat drench, although a Chlormequat spray was ineffective. They also reported that N-dimethylaminosuccinamic acid, (B-Nine); N-pyrrolidino-succinamic acid, (F529); indolacetic acid, (IAA) and Ethrel had no effect in hastening flowering.

Norton (1975) reported that a significant decrease in flowering time was achieved with both Chlormequat and Ancymidol. He considered Chlormequat to be superior to Ancymidol when considering cost and effectiveness. Drench treatments were more effective than spray in reducing flowering time. Drench and spray treated plants flowered 20 and 17 days earlier, respectively. Approximately 30 times more material is required with a drench than with a spray. The Ancymidol spray at 250 ppm was equally effective but is more expensive per plant. He also reported that the effect of supplementary lighting and growth retardant treatments were additive in decreasing time to flower, and observed that Chlormequat was still effective in controlling height even when supplementary light was used. Those results were confirmed by Armitage *et al.* (1978) and Konjoian and Tayama (1978).

Carlson (1976) applied Chlormequat and Ancymidol to ten cultivars of seed geraniums and found that days to flower, fresh weight, total height and vegetative height were lower on all growth retardant treatments when compared to the control. Number of breaks, number of flowers and number of buds were also higher on treated plants. He also reported that 200 ppm Ancymidol and 1500 ppm Chlormequat were the best concentrations for each product for all parameters measured.

Many authors have observed that Chlormequat sprays cause a bleaching of chlorophyll from the leaves of treated plants. It has been reported that yellow spots appear on older leaves after a Chlormequat spray, but it is not persistent and does not detract from the appearance of finished plants (Mastarlez, 1977).

Pawlowski *et al.* (1969) working with time of Chlormequat application, reported that the effect of the growth retardant on hastening flowering depends on the time of treatment. For a long time it was not clear if the earlier flowering was achieved with growth retardants because of an earlier induction or because of an accelerated development of the flower sprout. Jansen (1973) working with seed geraniums and Chlormequat treatments at zero, one and two applications, reported that Chlormequat actually causes early induction by eight to 14 days as compared to the control. He observed the flower formation through microtome sections of the stem apex. He suggested that Chlormequat "replaces" a part of the necessary light summation for the flower release.

Other than growth retardants, some products have been used experimentally to decrease time to flower of seed geraniums. Heins *et al.* (1978) included gibberellic acid (GA_3) to reduce flowering time, when sprayed at five to 15 ppm, in a list of growth regulators for seed geraniums. According to their recommendation GA_3 should decrease flowering time by ten to 21 days (depending on cultivar), when sprayed when flower buds are first seen down in the canopy. This effect should be considered as an acceleration of flower opening, after the flower is formed.

MATERIALS AND METHODS

Introduction

Two simultaneous experiments were conducted with the growth retardants Chlormequat and Ancymidol on seed geraniums. The objective of the first experiment was to evaluate the effect of repeated applications of growth retardants on the growth and flowering of seed geraniums. The second experiment was done to study the effect of time of application of growth retardants.

The *Pelargonium* x *hortorum* Bailey seed cultivars 'Sprinter Scarlet' and 'Sprinter Salmon' were used. The tested growth retardants were: (2-chlorethyl) trimethyl-ammonium chloride, (Chlormequat or CCC) and x-cyclorpro-pyl-x-(4-methoxyphenyl)-5-pyrimidline-methanol, (Ancymidol or A-Rest). The concentrations used were 1500 ppm CCC and 200 ppm A-Rest. The growth retardants were sprayed to run-off, with a hand sprayer ("Poly-Spray"). The applications were done between 5:00 p.m. and 6:00 p.m. and the next watering was done after a minimum of 24 hours interval.

<u>Cultural Conditions</u>

Each experiment was run twice. For the first run, seeds were sown in Speedling Mix (a peat-vermiculite mix manufactured by Speedling Inc., Sun City, FL) in plastic master flats on 2/23/78. In the second run seeds were sown on 4/17/78; Jiffy Mix (a peat-lite mix manufactured by Jiffy-Pot Company of America) was used as the germination medium in the same plastic flats of the first run. For both runs the seeds were germinated under mist at 21-24°C (70-75°F). Two days before transplanting the flats with the seedlings were removed from the mist bench.

Twenty-one days after sowing, for both runs, the seedlings were transplanted to 7.6 cm (3 inches) plastic cells and grown until the end of each experiment. The growing medium for the first run was Speedling Mix with 3 Kg/m^3 (5 lb/yard^3) of Osmocote (18-6-12). Because this mix did not dry out uniformly under cloudy Michigan conditions, a 1:1:1 medium by volume of soil:peat: perlite with 0.8 Kg/m^3 superphosphate (0-20-0) was used for the second run.

Greenhouse temperatures were set at 17°C (62°F) night and 21°C (70°F) day for both runs. Actual greenhouse temperatures were measured by thermograph (Taylor Instruments, Asheville, NC). Day temperatures averaged

26.7°C (80°F) and 27.2°C (81°F) for the first and second run, respectively. Night temperatures averaged 15°C (59°F) and 16.7°C (62°F) for each run.

Three days after transplanting a soil drench of 0.6 g (35% wettable powder) of dimethylaminobenzenediazo sodium sulfonate (Dexon) and 0.3 g (75% wettable powder) of pentechloronitro benzene (Terraclor) per liter of water was applied on both treatments for both runs.

Soil analyses were done at the beginning of each experiment, and thereafter weekly soil samples were taken to determine pH and soluble salts until the end of each experiment. Constant liquid feed of 200 ppm 25-0-25 was applied during each irrigation. The pH of the irrigation water was maintained at 6.0 by addition of phosphoric acid to the fertilizer stock solution.

Experimental Design and Treatments

A derivation of the split-plot design was used for the two experiments in both runs. This design was used because of the nature of the experiments, and to emphasize the timing treatments which were assigned to the last sub-plot for each case.

On Experiment I (number of applications) a split-split-plot was used for the first run, and a split-split-split-plot for the second run. In the first run the spacing of nine plants per square foot was used, and the design configuration with the treatments was as follows:

- blocks: 3
- cultivars: 2
  - A — Sprinter Scarlett
  - B — Sprinter Salmon
- chemicals: 2
  - A — Chlormequat (CCC)
  - B — Ancymidol (A-Rest)
- timing: 5

Number of Applications	Time of Application Days from Sowing
0 (control)	—
1	35
2	35 + 42
3	35 + 42 + 77
4	35 + 42 + 77 + 84

In the second run two spacing treatments were included. All the other sub-plots were the same as the first run. The spacing treatments used were: A — 9 pots/sq.ft. and B — 16 pots/sq.ft. (pot-to-pot). In the first run a total of 600 plants were used, with ten plants for each sub-sub-plot per block. In the second run also 600 plants were used, with five plants for each sub-sub-sub-plot per block.

On Experiment II (time of application) a split-split-plot was used on both runs. The design configuration was as follows:

- blocks: 3
- cultivars: 2
  - A — Sprinter Scarlet
  - B — Sprinter Salmon
- chemicals: 2
  - A — Chlormequat (CCC)
  - B — Ancymidol (A-Rest)
- timing: 7

Treatment Number	Time of Application Days from Sowing
1 (control)	—
2	14
3	21
4	28
5	35
6	42
7	35 + 42

In this experiment a treatment with double applications (number 7) was included, because it was widely recommended for seed geraniums. In the first run a total of 420 plants was used, with five plants for each sub-sub-plot per block. In the second run 14 plants were used for each sub-sub-plot per block, with a total of 1,176 plants. A higher number of plants was used here because weekly random plant samples were taken from each timing treatment of Sprinter Scarlet to study the meristem development.

For the two experiments in both runs all the experimental units were randomly distributed at the beginning of the experimental period.

Parameters Measured

The parameters were recorded on the day of the opening of the first floret on the first inflorescence. In the first run the following parameters were taken on both experiments: days to flower from sowing; floret size (cm), measured across the central petals immediately under the two uppermost petals; vegetative plant height (cm), measured from soil line to the uppermost leaf held parallel to the soil; total plant height (cm), measured from the soil line to the upper floret corolla; number of flower stalks; leaf diameter (cm), measured across the greatest width of the blade of the first fully developed leaf and fresh weight (g), where plants were cut at the soil line and weighed on a Mettler balance.

On the second run the number of breaks (growing point 0.5 cm from the stem or greater) were recorded instead of number of flower stalks. Number of open florets at flowering time was also recorded on the second run. All the other parameters were the same as in the first run.

On the first run the plants from one block of each experiment were not weighed. They were transplanted on 6/30/78 to garden conditions to see how the treated plants would react under such conditions. Vegetative height, total height, number of breaks and leaf diameter were recorded on 8/25/78.

A study of the meristematic changes which occurred on Sprinter Scarlet plants from Experiment II (time of application) was conducted during the second run. To observe this the terminals of randomly chosen plants of all treatments were examined through microtome sections. This material was collected weekly starting on 5/8/78 (21 days after sowing) until the flower initiation was observed on all treatments. The technique used was described by Johansen (1940). The material was collected and immediately fixed in FAA (50% ethyl alcohol, 10% formaldehyde, 5% glacial acetic acid and 35% water). The samples were dehydrated with the tertiary butyl alcohol method and infiltrated with paraffin. Paraffin boats were prepared and each plant terminal was mounted on wood blocks. Sections of ten microns were cut on the microtome. The sections were fixed on slides with Wiver fixator and stained with Sass' Modified Mayer's Haemalum.

The meristem differentiation time was considered to be between the number of days of observed change and the previous observation time.

Analyses of Results

The result section was divided in three parts. Part A has the results of the Experiment I, part B has the results of Experiment II and part C has the results of the meristematic studies.

The data of part A and part B, except the data for plants transplanted to garden conditions, were analyzed using the SPSS package on the Michigan State University CDC 6500 computer for analyses of variance and also for graph plotting. Multiple comparisons were done by LSD at 5% level, using an electronic calculator Sharp model EL-5806.

No statistical analyses were conducted on the results from the meristematic study and on data of plants under garden conditions; since, it was not possible to have replications on both works.

RESULTS

Part A — Experiment I

Number of Applications

Tables 1 and 2 summarize the results of the first and second run respectively. These data are averages for each split-treatment over the other treatments.

In the first run the only significant differences between the cultivars was for days to flower and number of flower stalks. Sprinter Salmon flowered two days earlier than Sprinter Scarlet, and with a slightly higher number of flower stalks. In the second run the only significant different parameter was vegetative height, Sprinter Salmon was slightly shorter than Sprinter Scarlet.

In the first run there was no significant difference on time to flower between CCC and A-Rest. In the second run CCC treated plants flowered four days earlier than the A-Rest treated plants. In the first run A-Rest was more effective in reducing all the other parameters except the number of flower stalks, which was higher for A-Rest than for CCC treated plants. In the second run A-Rest treated plants had greater vegetative height and leaf diameter than the CCC treated plants. For this run all the other parameters were not significantly different.

The spacing treatment was included only in the second run. The pot-to-pot spacing (16 plants/sq.ft.) had a greater plant response on total height and lower number of breaks than the nine plants per square foot spacing. All the other parameters were not significantly different for both spacings.

The results of the number of application treatments were very consistent on both runs. For almost all the parameters measured in both runs, the control treatment showed higher values than the other treatments. Only the number of flower stalks and the number of breaks were lower on control than on the other treatments. The days to flower in both runs did not differ significantly among the application treatments. With increasing number of applications, there was a tendency to decrease floret size, number of florets, vegetative height, total height, leaf diameter and fresh weight. The number of flower stalks and number of breaks seemed to increase with increasing number of applications.

Figures 1 to 9 show the trends of increasing number of applications of CCC and A-Rest for each parameter measured in each run:

Days to Flower (Fig. 1) - Plants of the second run (sown on 4/17/78) flowered in average one week earlier than plants of the first run (sown on 2/3/78). In both runs plants treated with both growth retardants flowered earlier than the control, although more than two applications of CCC in the first run and A-Rest in the second run did not seem to be very efficient. In the first run the effect of Ancymidol was greater than Chlormequat, but in the second run the opposite result was observed.

Floret Size (Fig. 2) - It was observed that as number of applications increased, floret size decreased. The floret size for all treatments was larger on the second run than on the first run. In both runs A-Rest treated plants showed smaller florets than CCC treated plants.

Number of Florets (Fig. 3) - This parameter was considered only in the second run. It was observed that as number of applications increased, number of florets decreased. The effect of CCC seemed to be greater than A-Rest for this parameter, although the sharpest response was observed with three applications of A-Rest.

Vegetative and Total Height (Figs. 4 and 5) - Increasing number of applications of both retardants in both runs had a tendency to decrease plant height. In the first run A-Rest was very clearly more effective than CCC.

In the second run no significant difference was observed between both growth retardants. Plants in the first run were generally shorter than plants in the second run.

Number of Flower Stalks (Fig. 6) - This parameter was considered only in the first run. Growth retardant treated plants had a tendency to produce more flower stalks than the control. A-Rest was significantly more efficient than the CCC treatments. The trends were more pronounced on A-Rest treatments than on CCC treatments.

Number of Breaks (Fig. 7) - This parameter was taken only in the second run. There was a very clear trend to increase number of breaks with increasing number of applications. In this case CCC and A-Rest acted almost in the same manner.

Leaf Diameter (Fig. 8) - Both growth retardants in both runs showed a tendency to decrease leaf size with increased number of applications. A-Rest was more effective than CCC in the first run, although both growth retardants gave very similar results for the second run.

Fresh Weight (Fig. 9) - The same general trends observed for leaf diameter, plant height, number of florets and floret size, were observed here. The fresh weight also tended to decrease with increasing number of applications of growth retardants. A-Rest again was more effective than CCC in the first run, although no significant difference between the two growth retardants was observed in the second run.

Figure 10 shows the comparisons among all time of application treatments for each cultivar in the first run.

Table 3 shows the data taken from plants of the first run, after they were transplanted to garden conditions. Although it was not possible to make statistical analyses on these data, the effect of A-Rest seemed to last longer than the effect of CCC in controlling plant growth. The CCC treated plants seemed to have a very similar growth rate to control plants, after transplant. In general the tendency for greater growth control with increasing number of applications still remained after plants were transplanted to garden conditions.

TABLE 1. Comparison of cultivars, growth retardants and number of applications. Geranium seeds sown on 2/23/78.

(1) Significance of F.: NS = Non-significant; * = significant at 5% level; ** = significant at 1% level.

(2) Mean separation: All treatments means with the same letter are not significantly different by LSD at 5% level.

	Days to Flower	Floret Size (cm)	Veg. Height (cm)	Total Height (cm)	Number Flower Stalks	Leaf Diameter (cm)	Fresh Weight (g)
Cultivar							
Sprinter Scarlet	106.7	3.366	6.58	19.15	1.39	5.62	21.01
Sprinter Salmon	104.9	3.623	7.20	19.03	1.72	5.75	23.99
Sig. of F. (1)	*	NS	NS	NS	**	NS	NS
Chemical							
CCC	107.26	3.66	8.00	21.53	1.35	6.37	25.07
A-Rest	104.57	3.27	5.59	16.47	1.71	4.95	19.25
Sig. of F. (1)	NS	**	**	**	*	**	*
No. of Applications (2)							
0	108.8 a	3.90 a	9.56 a	23.81 a	1.25 a	7.28 a	29.88 a
1	105.6 b	3.50 b	7.31 b	20.61 b	1.59 b	5.77 b	23.69 b
2	105.4 b	3.40 bc	6.09 c	18.48 c	1.56 b	5.31 c	20.14 c
3	104.7 b	3.30 c	5.72 c	17.08 d	1.56 b	5.09 cd	18.86 c
4	105.2 b	3.10 d	5.45 c	15.38 e	1.67 b	4.95 d	18.63 c

TABLE 2. Comparison of cultivars, spacing, growth retardants and number of applications. Geranium seeds sowed on 4/17/78.

(1) Significance of F.: NS = non-significant; * = significant at 5% level; ** = significant at 1% level.

(2) Mean separation: All treatments means with the same letter are not significantly different by LSD at 5% level.

	Days to Flower	Floret Size (cm)	Number Florets	Veg. Height (cm)	Total Height (cm)	Number Breaks	Leaf Diameter (cm)	Fresh Weight (g)
Cultivar								
Sprinter Scarlet	96.81	3.71	1.33	10.15	22.25	2.33	7.80	30.98
Sprinter Salmon	95.38	3.86	1.30	9.14	20.95	2.38	7.71	27.99
Sig. of F. (1)	NS	NS	NS	**	NS	NS	NS	NS
Spacing								
9/sq. ft.	94.95	3.80	1.31	9.18	20.37	2.68	7.62	29.52
10/sq. ft.	97.28	3.77	1.33	10.12	22.84	2.00	7.90	29.38
Sig. of F. (1)	NS	NS	NS	NS	**	**	NS	NS
Chemical								
CCC	94.20	3.80	1.29	9.08	21.68	2.37	7.58	28.63
A-Rest	97.98	3.77	1.34	10.20	21.49	2.33	7.93	30.27
Sig. of F. (1)	**	NS	NS	**	NS	NS	*	NS
No. of Applications (2)								
0	100.66 a	4.15 a	1.46 a	12.58 a	25.33 a	1.60 a	9.45 a	38.64 a
1	95.37 b	4.01 ab	1.32 ab	10.08 b	22.85 ab	2.28 bc	7.98 b	29.89 b
2	93.46 b	3.44 b	1.26 b	8.48 c	21.17 b	2.05 ab	7.21 c	26.24 c
3	95.08 b	3.44 c	1.24 b	8.81 c	20.68 bc	2.68 cd	7.07 c	26.04 c
4	95.37 b	3.94 c	1.29 b	8.29 c	18.01 c	3.11 d	7.07 c	26.63 c

TABLE 3. Comparison of cultivars, growth retardants and number of applications of plants under garden conditions. Geranium seeds were sown on 2/23/78 and the seedlings were transplanted on 6/30/78. Data taken on 8/25/78.

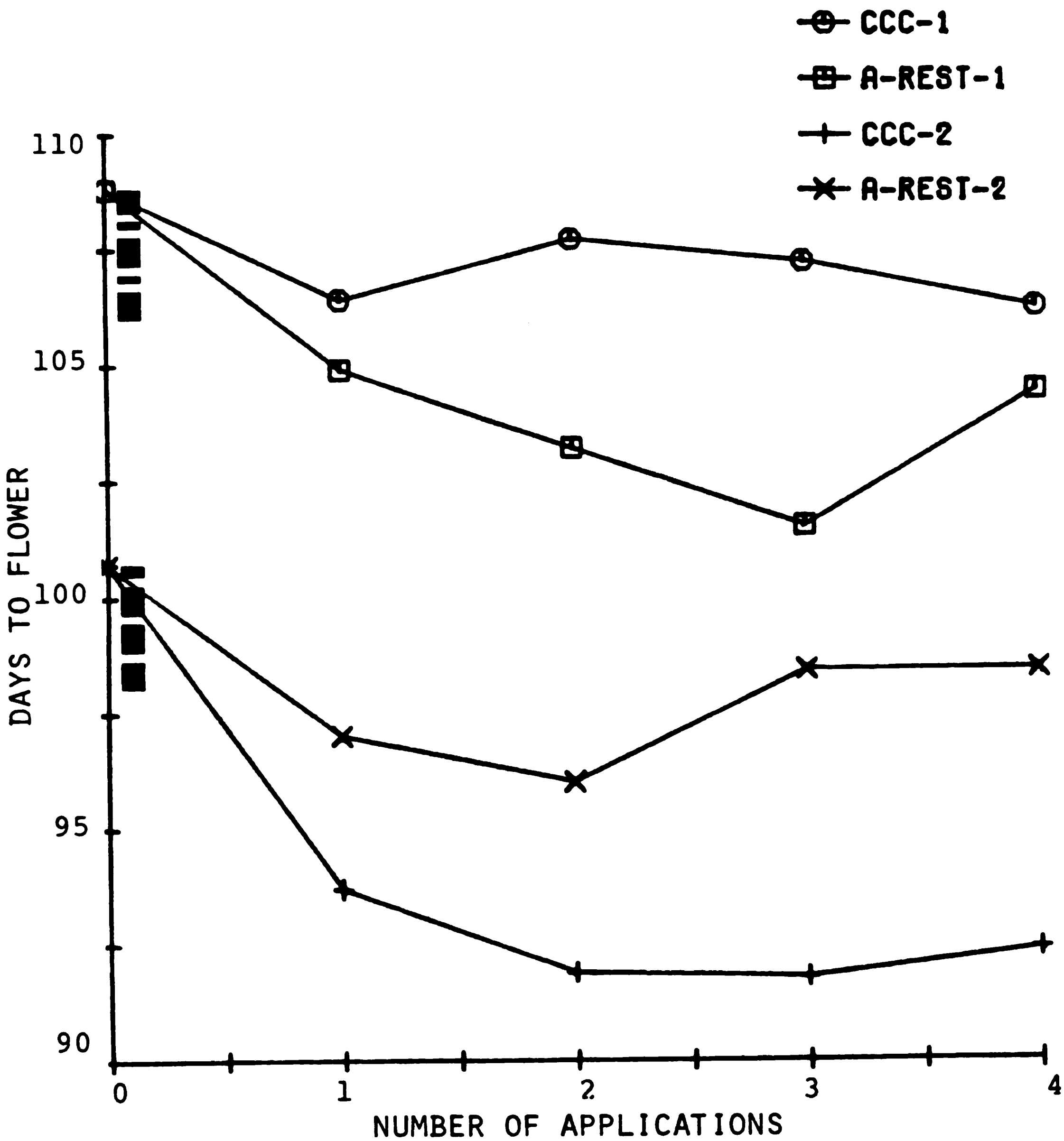
	Vegetative Height (cm)	Total Height (cm)	Number of Breaks	Leaf Diameter (cm)
Cultivar				
Sprinter Scarlet	16.55	34.27	9.58	8.74
Sprinter Salmon	12.73	25.18	7.43	7.46
Chemical				
CCC	17.29	32.72	9.68	8.81
A-Rest	11.98	26.73	7.32	7.39
No. of Applications				
0 (control)	17.18	32.84	7.41	9.09
1	16.00	30.46	8.41	8.42
2	14.18	29.34	9.00	7.93
3	12.54	27.23	8.62	7.41
4	13.29	28.25	9.08	7.65

Figure 1

Graph showing days to flower vs. number of applications. CCC-1 and A-Rest 1 are treatments for the first run, started on 2 23 78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4 17 78.

\- value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the first run.

\- value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the second run.



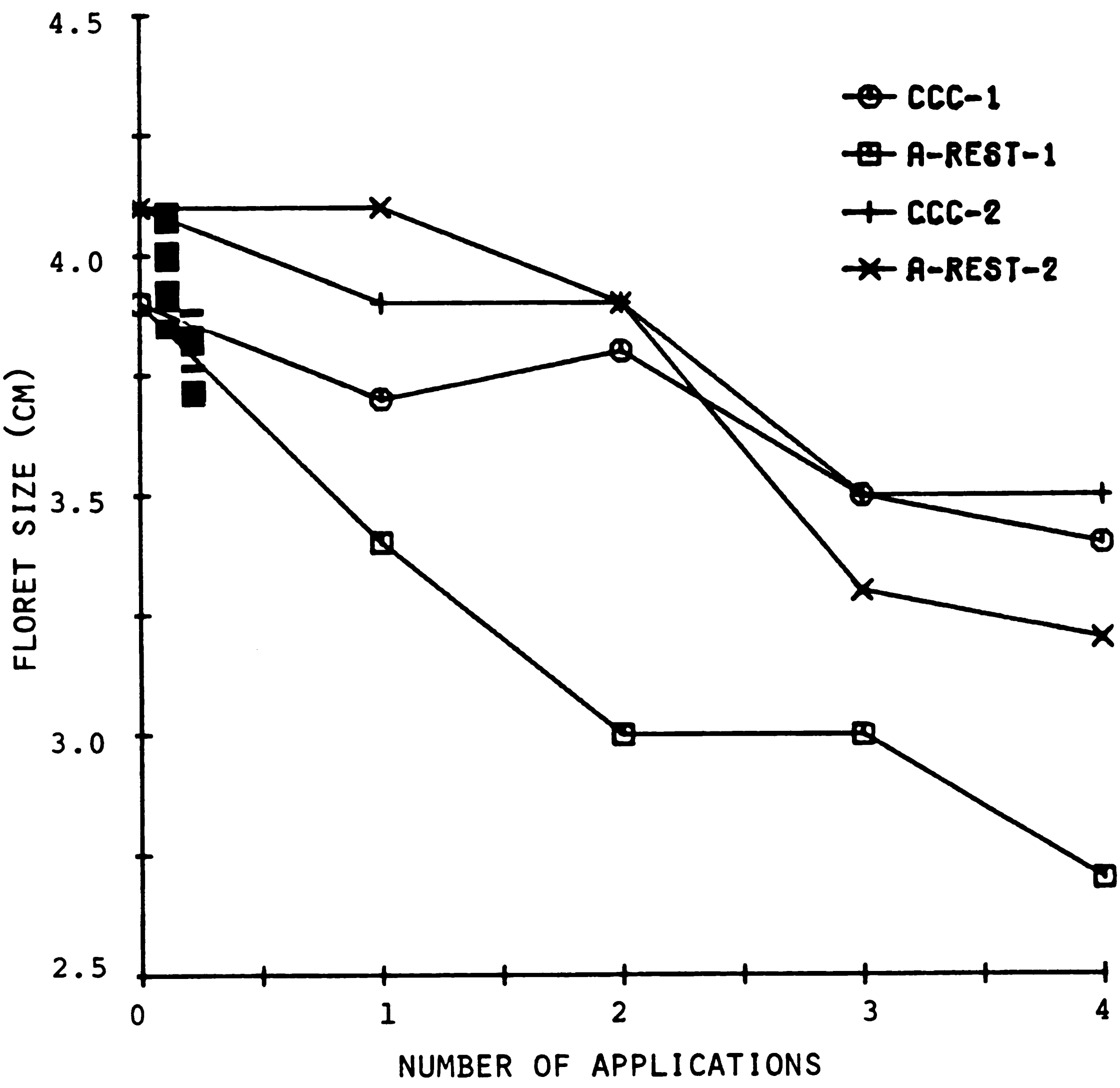
CCC-1
A-REST-1
CCC-2
A-REST-2
110
105
100
95
90
DAYS TO FLOWER
0
1
2
3
4
NUMBER OF APPLICATIONS

Figure 2

Graph showing floret size vs. number of applications. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

■I■ - value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the first run.

■■■ - value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the second run.



4.5
4.0
3.5
3.0
2.5
FLORET SIZE (CM)
0
1
2
3
4
NUMBER OF APPLICATIONS
CCC-1
A-REST-1
CCC-2
A-REST-2

Figure 3

Graph showing number of florets vs. number of applications. CCC-2 and A-Rest-2 are treatments for the second run started on 4/17/78.

■■■ - value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the second run.

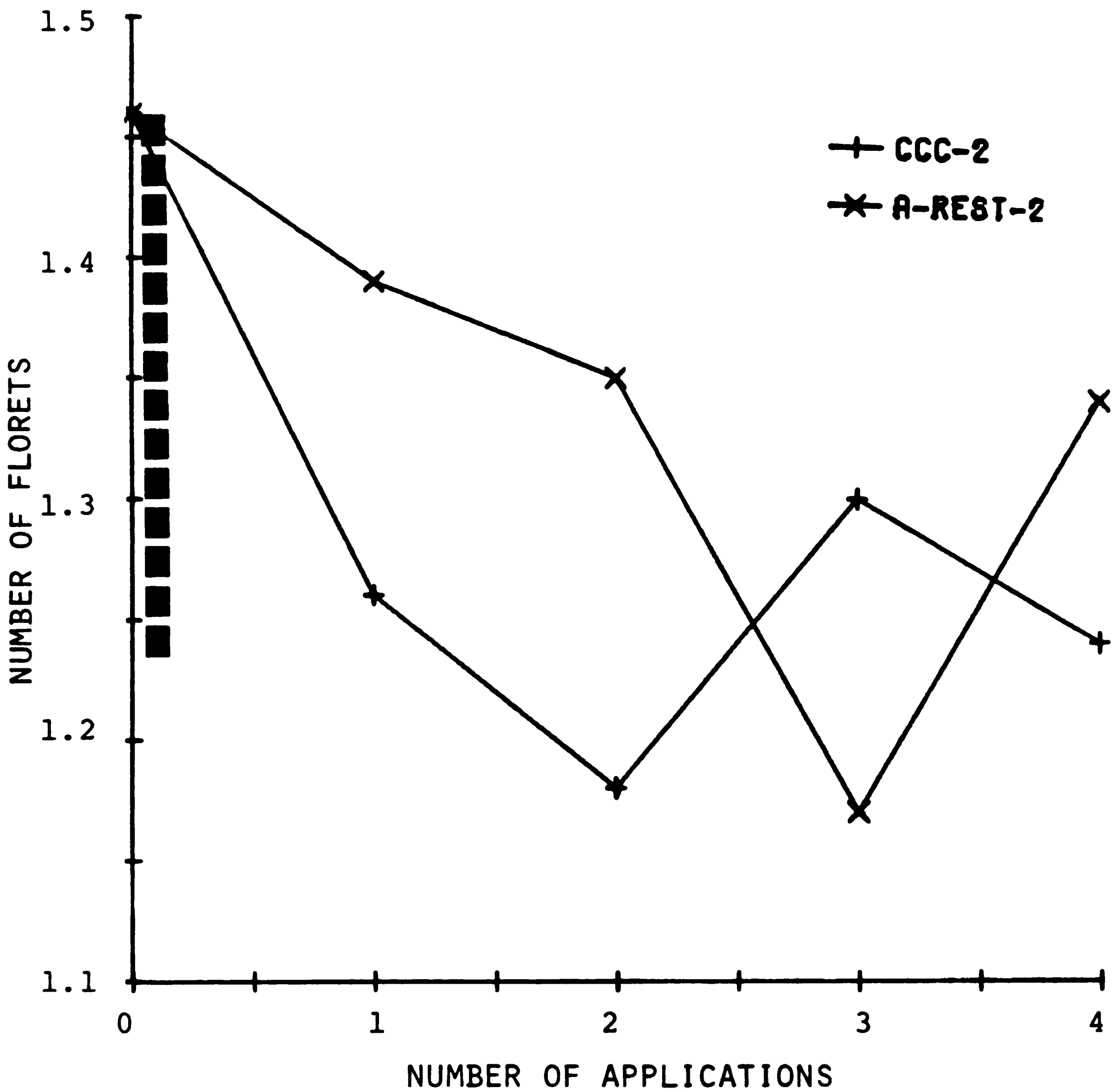

CCC-2
A-REST-2
1.5
1.4
1.3
1.2
1.1
NUMBER OF FLORETS
0
1
2
3
4
NUMBER OF APPLICATIONS

Figure 4

Graph showing vegetative height vs. number of applications. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

- value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the first run.

- value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the second run.

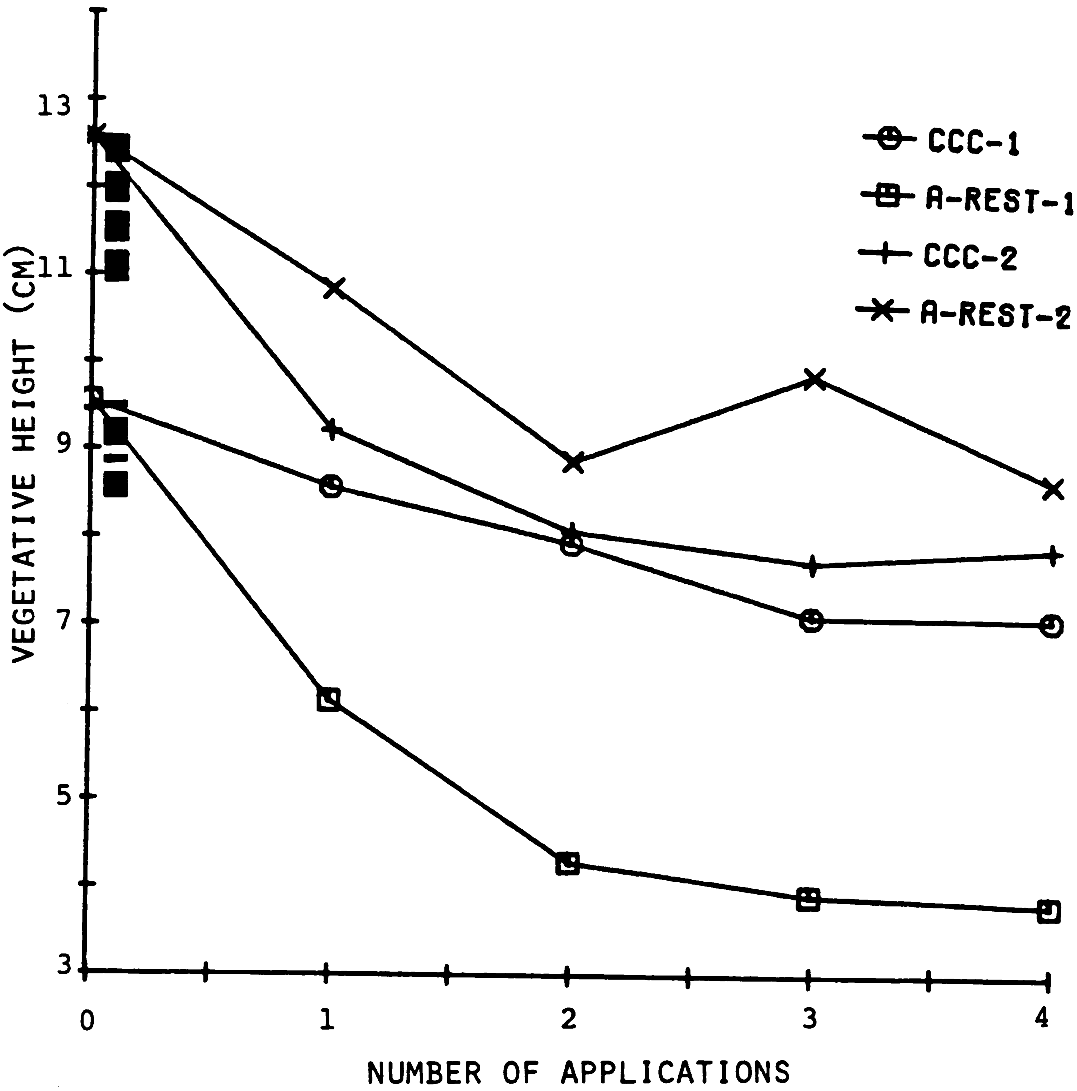

13
11
9
7
5
3
0
1
2
3
4
VEGETATIVE HEIGHT (CM)
NUMBER OF APPLICATIONS
CCC-1
A-REST-1
CCC-2
A-REST-2

Figure 5

Graph showing total height vs. number of applications. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

- value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the first run.

- value of LSD at 5% level for comparison of number of applications treatments for each growth treatment, in the second run.

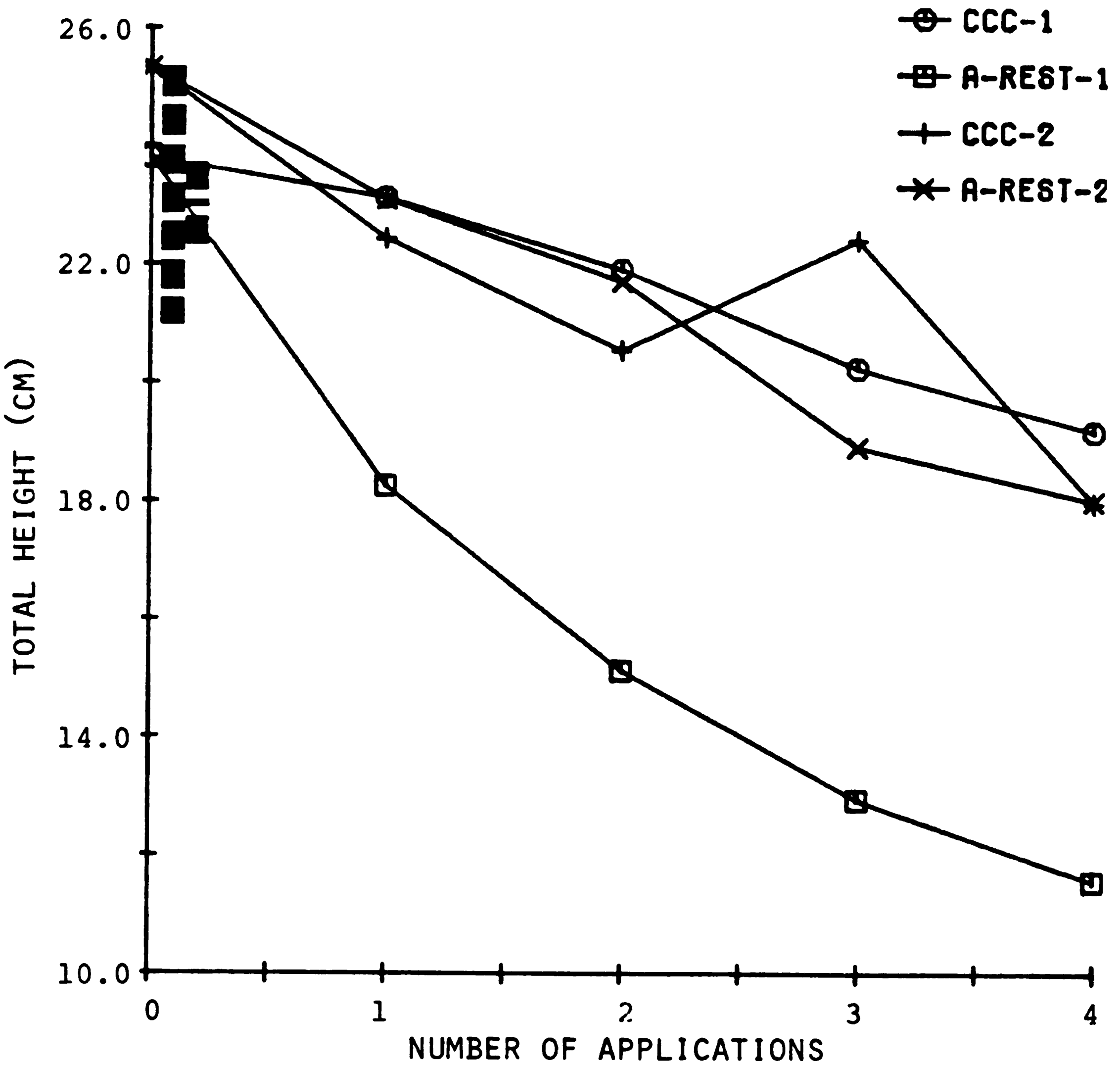

CCC-1
A-REST-1
CCC-2
A-REST-2
26.0
22.0
18.0
14.0
10.0
TOTAL HEIGHT (CM)
0
1
2
3
4
NUMBER OF APPLICATIONS

Figure 6

Graph showing number of flower stalks vs. number of applications. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78.

- value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the first run.

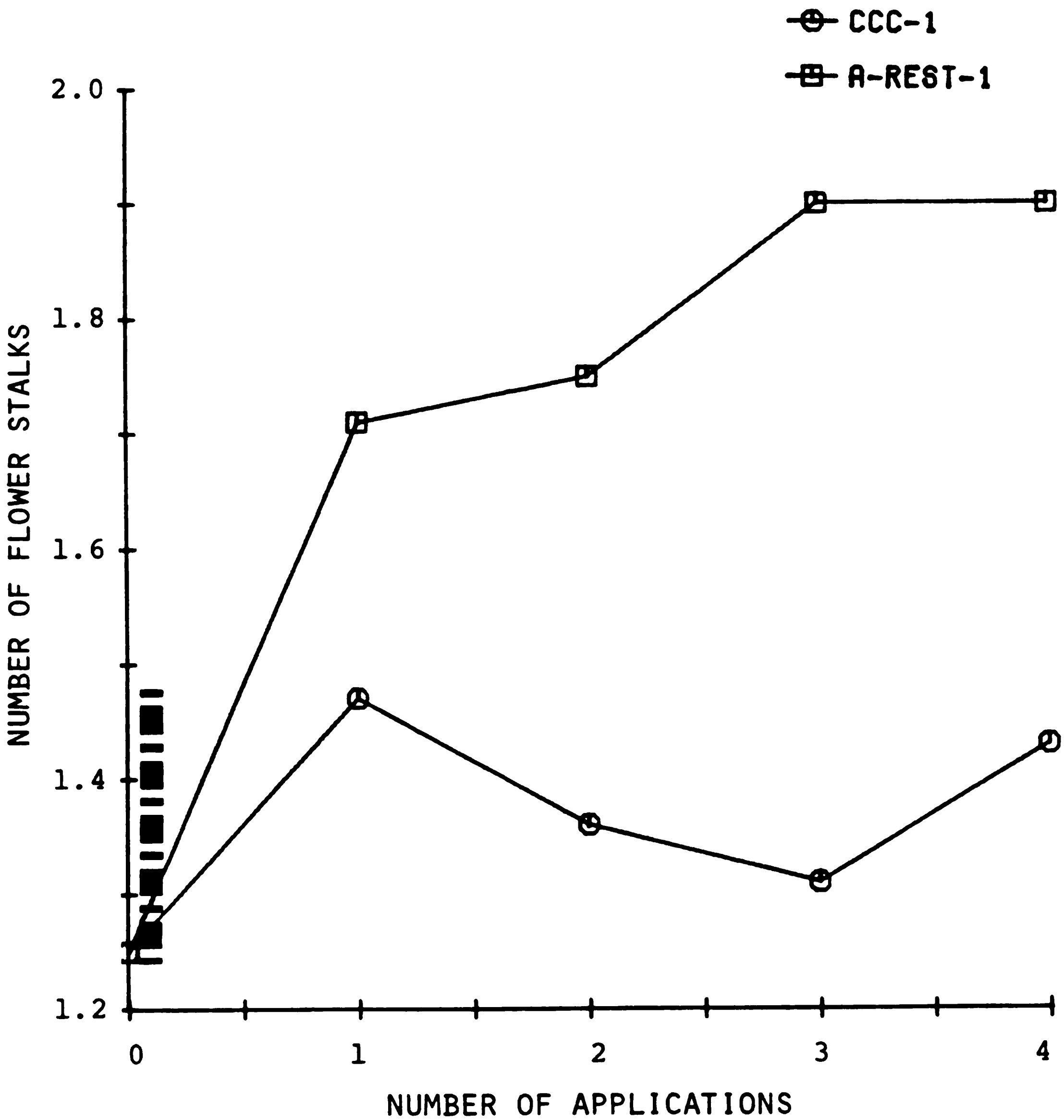

CCC-1
A-REST-1
2.0
1.8
1.6
1.4
1.2
NUMBER OF FLOWER STALKS
0
1
2
3
4
NUMBER OF APPLICATIONS

Figure 7

Graph showing number of breaks vs. number of applications. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

■■■ - value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the second run.

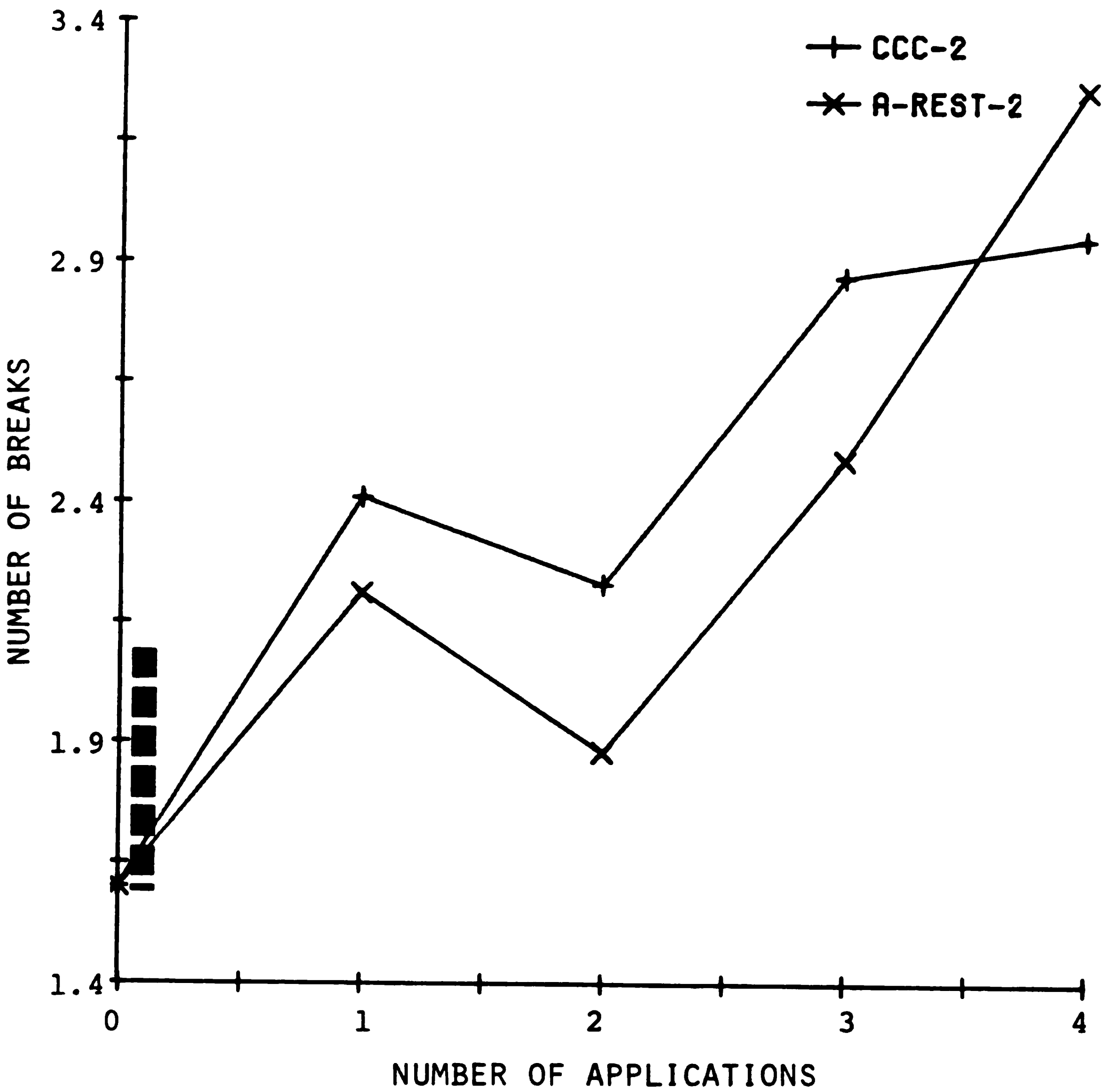
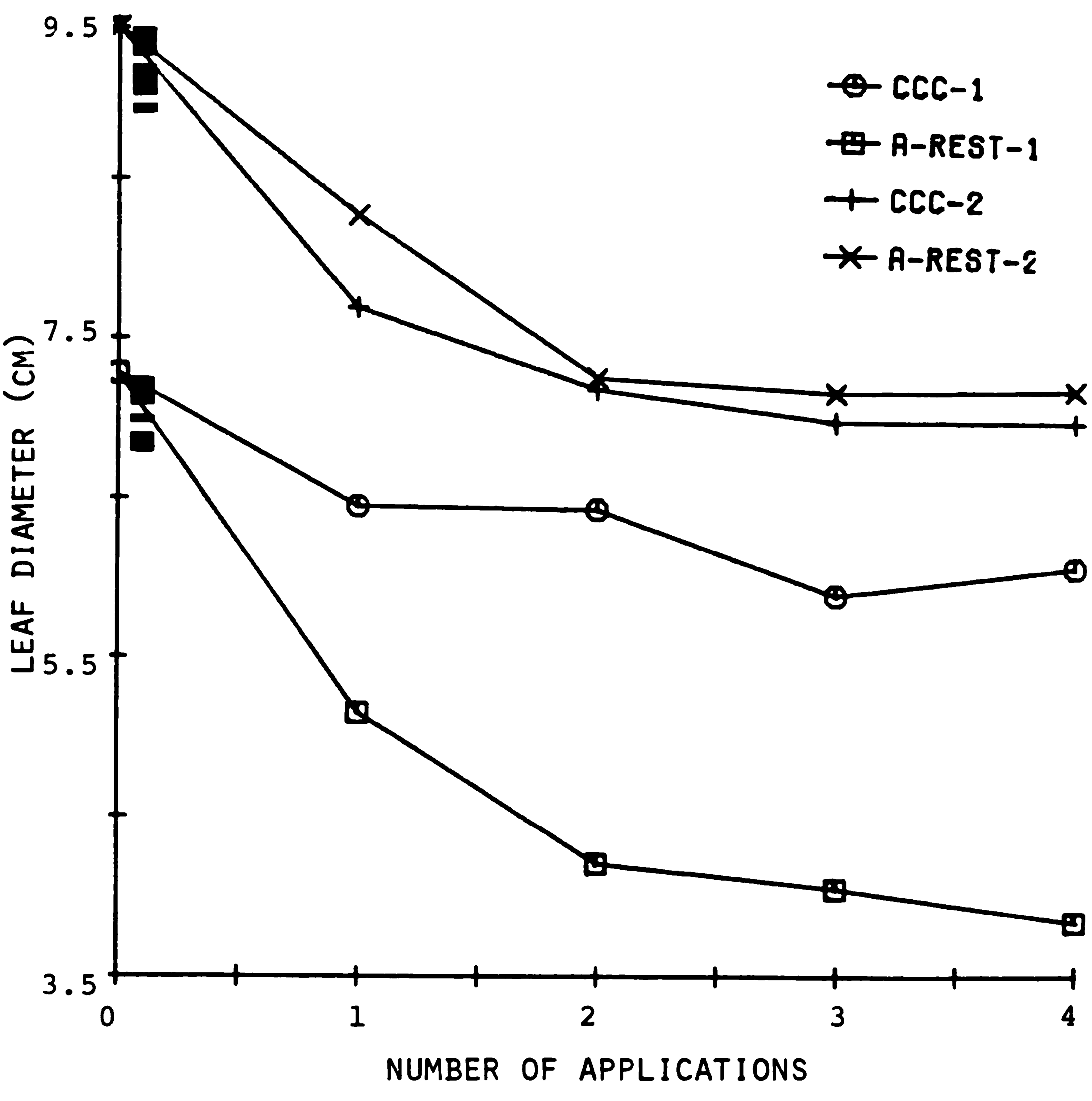

CCC-2
A-REST-2
3.4
2.9
2.4
1.9
1.4
NUMBER OF BREAKS
0
1
2
3
4
NUMBER OF APPLICATIONS

Figure 8

Graph showing leaf diameter vs. number of applications. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

- value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the first run.

- value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the second run.



CCC-1
A-REST-1
CCC-2
A-REST-2
9.5
7.5
5.5
3.5
LEAF DIAMETER (CM)
0
1
2
3
4
NUMBER OF APPLICATIONS

Figure 9

Graph showing fresh weight vs. number of applications. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

- value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, for the first run.

- value of LSD at 5% level for comparison of number of applications treatments for each growth retardant, in the second run.

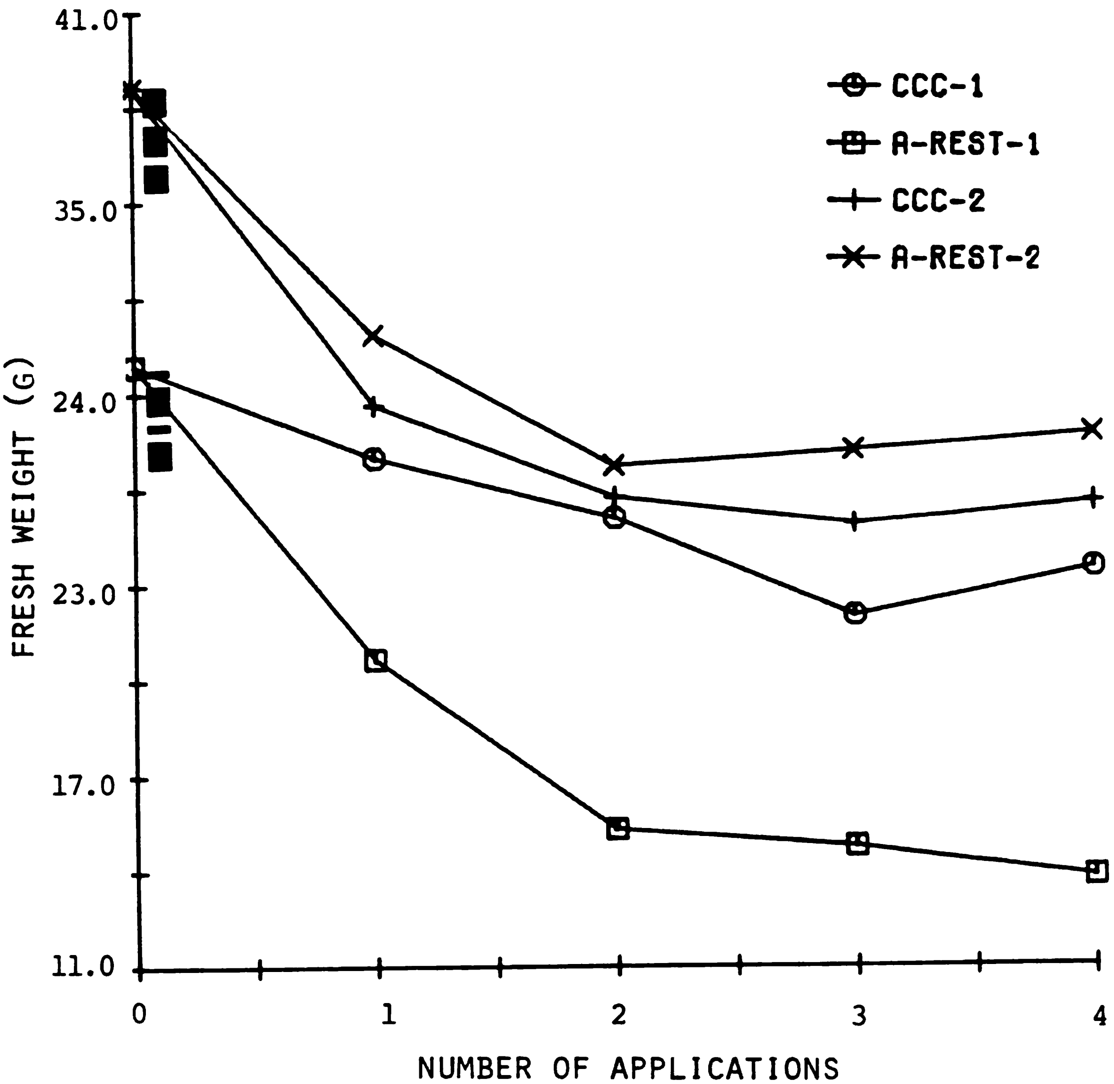

41.0
35.0
24.0
23.0
17.0
11.0
FRESH WEIGHT (G)
0
1
2
3
4
NUMBER OF APPLICATIONS
CCC-1
A-REST-1
CCC-2
A-REST-2

Figure 10

Comparison among number of application treatments.

Check - untreated; 1 - application at 35 days;
2 - 35+42 days; 3 - 35+42+77 days; 4 - 35+42+77+84
days after sowing (seeds sown on 2/23/78).

a) Sprinter Scarlet plants treated with Chlormequat (CCC).

b) Sprinter Scarlet plants treated with Ancymidol (A-Rest).

c) Sprinter Salmon plants treated with Chlormequat (CCC).

d) Sprinter Salmon plants treated with Ancymidol (A-Rest).


JUNE 16
113 DAYS
SSC CHECK
CCC 1
2
3
4

a


JUNE 16
113 DAYS
SSC CHECK
AREST 1
2
3
4

b


JUNE 16
113 DAYS
SSA CHECK
CCC 1
2
3
4

c


JUNE 16
113 DAYS
SSA CHECK
AREST 1
2
3
4

d

RESULTS

Part B — Experiment II

Time of Application

Tables 4 and 5 summarize the results of the first and second run, respectively. These data are averages for each split-treatment over the other treatments.

The cultivar data are very consistent in both runs. Only total height in the first run was significantly higher in Sprinter Scarlet than Sprinter Salmon. All the other parameters were not significantly different between cultivars in both runs.

Similar to the results of Experiment I, the response to chemical treatments was very different in both runs. In the first run A-Rest showed a significant effect in reducing the values for almost all parameters, when compared with CCC. The number of flower stalks was higher on A-Rest as compared with CCC treatments. On the second run the values for all parameters were non-significant between both growth retardants, except floret size which was larger on the A-Rest as compared with the CCC treatments.

The time of application treatments showed a similar trend in both runs for all parameters. Late application appeared to decrease time to flower, floret size, number of florets, vegetative height, total height, leaf diameter and fresh weight. Number of flower stalks and number of breaks appeared to increase as application got later.

The control treatment and the double application treatment resulted in the extreme values for all parameters measured. The control treatment was the lowest value for number of breaks and number of flower stalks, and the highest value for all the other parameters. The double application showed opposite results than the control for all parameters measured, except number of breaks.

Figures 11 to 19 show the trends of time of application, compared with the control and the double application. Each figure shows the trends for CCC and A-Rest in each run for each parameter measured. On the X axis of each graph the treatment numbers from 1 to 6 represent respectively: control, 14 days after sowing, 21 days, 28 days, 35 days and 42 days. The treatment number 7 represents the double application at 35 and 42 days. The control and double application data were also plotted in order to show their responses compared with the other treatments. In general the differences observed on the number of applications experiments between the two runs were also observed on the time of application experiments.

Days to Flower (Fig. 11) - Plants of the second run flowered approximately seven days earlier than plants of the first run. All growth retardant treatments flowered earlier than the control. In the first run A-Rest was slightly more effective than CCC, but in the second run there were no significant differences. On the results of the second run it is very clear that the responses to different time of application were very similar, although all growth retardant treatments flowered earlier than the control.

Floret Size (Fig. 12) - As the time of application got later there was a tendency to decrease floret size in both runs for both growth retardants. The effect of A-Rest in the first run was slightly higher than the effect of CCC, but in the second run no significant difference was observed.

Number of Florets (Fig. 13) - Although the responses to CCC and A-Rest at 14 days after sowing were slightly different, both growth retardants showed a tendency to decrease the number of florets when the application got later. For both growth retardants a double application seemed to cause greater response than any single application.

<u>Vegetative and Total Height (Figs. 14 and 15)</u> - Later application corresponded to smaller plants for both growth retardants in both runs. In the first run A-Rest was much more effective in controlling height than CCC was. In the second run this difference was not significant.

<u>Number of Flower Stalks (Fig. 16)</u> - Later application also corresponded to higher number of flower stalks for both growth retardants. Applications of A-Rest at 35 days and the double application of CCC seemed to cause a small decrease in the response, although it was not significant.

<u>Number of Breaks (Fig. 17)</u> - Number of breaks seemed to increase with later application, although the response occurred in an erratic fashion.

<u>Leaf Diameter (Fig. 18)</u> - Once more the general trend was observed. As the application time got later, the leaf diameter of treated plants decreased. A-Rest was more efficient than CCC in the first run, but in the second run the difference was not significant between the two growth retardants.

<u>Fresh Weight (Fig. 19)</u> - As application got later the fresh weight decreased for both growth retardants in

both runs.

Figure 20 shows the comparison among all time of application treatments in the first run.

Table 6 shows the data taken from plants of the first run, after transplanted to garden conditions. Similar to the results of Experiment I, A-Rest seemed to have a longer effect than CCC in controlling plant growth. The general trend of greater growth control as application got later was still observed after plants were transplanted to garden conditions.

TABLE 4. Comparison of cultivars, growth retardants and time of application. Geranium seeds sown on 2/23/78.

(1) Significance of F.: NS - non-significant; * = significant at 5% level; ** = significant at 1% level.

(2) Means separation: All treatments means with the same letter are not significantly different by LSD at 5% level.

	Days to Flower	Floret Size (cm)	Veg. Height (cm)	Total Height (cm)	Number Flower Stalks	Leaf Diameter (cm)	Fresh Weight (g)
Cultivar							
Sprinter Scarlet	106.64	3.67	8.40	22.26	1.41	6.82	17.23
Sprinter Salmon	105.78	3.73	7.91	20.05	1.59	6.73	15.76
Sig. of F. (1)	NS	NS	NS	*	NS	NS	NS
Chemical							
Chlormequat	107.4	3.83	9.04	22.78	1.36	7.38	17.31
Ancymidol	105.0	3.58	7.28	19.53	1.65	6.16	15.68
Sig. of F. (1)	**	*	**	**	**	**	*
Timing (2) - Day after Sowing							
Control	109.17 a	4.07 a	10.59 a	23.94 a	1.31 a	8.17 a	21.12 a
14	106.84 bc	3.90 ab	10.31 a	22.82 a	1.49 abc	7.76 b	19.52 ab
21	107.50 ab	3.81 bc	8.67 b	22.78 a	1.35 ab	7.07 c	17.38 bc
28	105.91 bcd	3.67 c	7.00 cd	20.02 b	1.50 bcd	6.28 d	14.67 d
35	105.50 cd	3.69 c	7.51 bc	20.74 b	1.68 d	6.22 d	15.78 cd
35-42	104.33 d	3.35 d	6.12 d	18.16 c	1.58 cd	5.71 e	12.77 e
42	104.25 d	3.42 d	6.94 cd	19.57 bc	1.64 cd	6.19 d	14.22 de

TABLE 5. Comparison of cultivars, growth retardants and time of application. Geranium seeds sown on 4/17/78.

(1) Significance of F.: NS = non-significant; * = significant at 5% level; ** = significant at 1% level.

(2) Means separation: All treatments means with the same letter are not significantly different by LSD at 5% level.

	Days to Flower	Floret Size (cm)	Number Florets	Veg. Height (cm)	Total Height (cm)	Number Breaks	Leaf Diameter (cm)	Fresh Weight (g)
Cultivar								
Sprinter Scarlet	96.78	3.98	1.43	9.92	24.42	1.48	7.57	29.50
Sprinter Salmon	94.83	4.29	1.24	10.04	23.37	1.91	8.06	30.65
Sig. of F. (1)	NS	NS	NS	NS	NS	NS	NS	NS
Chemical								
Chlormequat	95.45	4.05	1.33	9.44	23.58	1.64	7.73	29.08
Ancymidol	96.16	4.22	1.34	10.52	24.20	1.75	7.89	31.07
Sig. of F. (1)	NS	*	NS	NS	NS	NS	NS	NS
Timing (2) - Day after Sowing								
Control	100.58 a	4.33 a	1.40 a	11.99 a	25.99 a	1.38 a	9.38 a	36.69 a
14	94.91 b	4.20 ab	1.35 a	10.59 b	24.79 ab	1.80 ab	8.21 b	32.74 b
21	95.42 b	4.17 b	1.38 a	10.46 b	24.87 ab	1.63 ab	8.15 b	30.21 bc
28	95.34 b	4.11 bc	1.31 a	9.66 bc	23.69 bc	1.92 b	7.49 c	29.89 bc
35	94.42 b	4.08 bc	1.32 a	9.20 cd	22.52 c	1.97 b	7.35 cd	28.55 c
35-42	94.08 b	4.03 c	1.22 a	8.39 d	22.36 c	1.68 ab	6.87 d	25.06 d
42	95.91 b	4.02 c	1.36 a	9.57 bc	23.08 c	1.49 ab	7.24 cd	27.40 cd

TABLE 6. Comparison of cultivars, growth retardants and time of application of plants under garden conditions. Geranium seeds were sown on 2/23/78 and the seedlings were transplanted on 6/30/78. Data taken on 8/25/78.

	Vegetative Height (cm)	Total Height (cm)	Number of Breaks	Leaf Diameter (cm)
Cultivar				
Sprinter Scarlet	27.81	45.21	10.63	9.49
Sprinter Salmon	19.57	34.23	8.62	8.56
Chemical				
Chlormequat	26.69	42.65	10.53	9.45
Ancymidol	22.18	36.74	8.73	8.60
Time of Application (Day after Sowing)				
Control	25.03	40.74	9.71	9.84
14	27.47	45.25	10.43	10.04
21	25.96	41.58	9.06	9.23
28	22.40	37.20	8.87	8.44
35	23.40	37.78	8.81	8.45
42	24.28	38.62	9.37	8.43
35 & 42	22.52	36.86	9.87	8.66

Figure 11

Graph showing days to flower vs. time of application. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

Treatment number: 1 = control; 2 = application at 14 days after sown; 3 = 21 days; 4 = 28 days; 5 = 35 days; 6 = 42 days; 7 = 35 + 42 days.

- value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the first run.

- value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the second run.

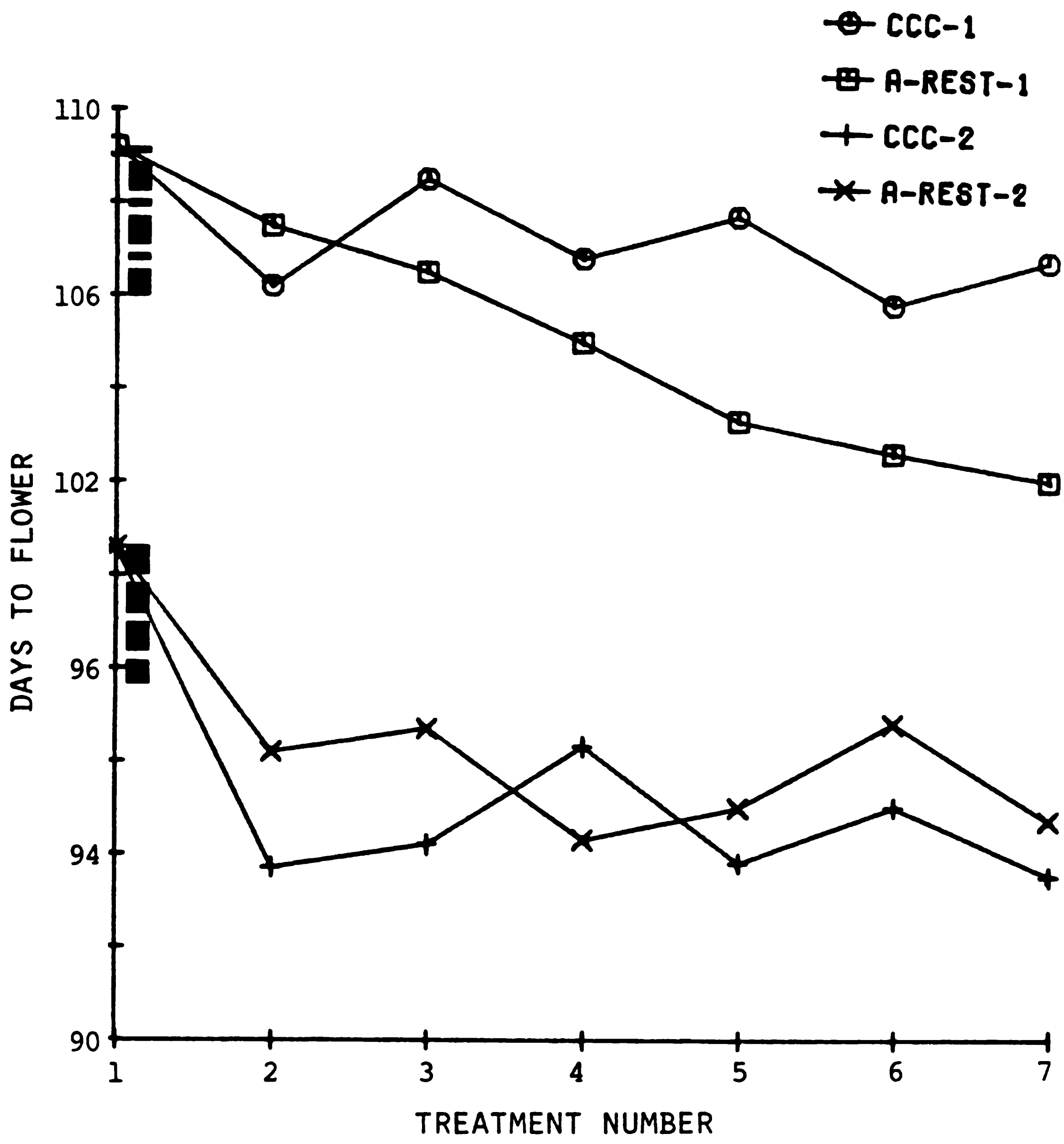

CCC-1
A-REST-1
CCC-2
A-REST-2
110
106
102
96
94
90
DAYS TO FLOWER
1
2
3
4
5
6
7
TREATMENT NUMBER

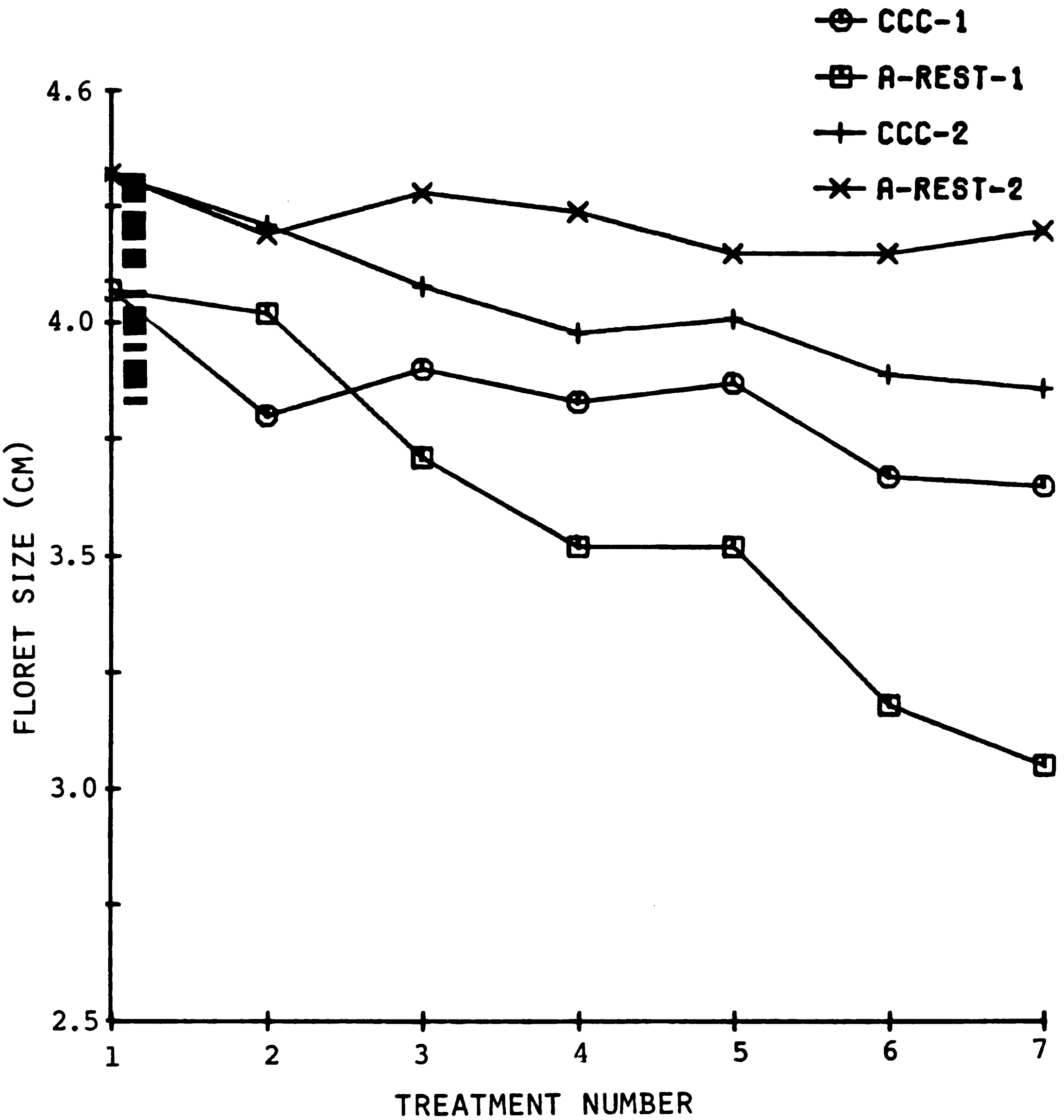
Figure 12

Graph showing floret size vs. time of application. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

Treatment number: 1 = control; 2 = application at 14 days after sown; 3 - 21 days; 4 = 28 days; 5 = 35 days; 6 = 42 days; 7 = 35 + 42 days.

■I■ - value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the first run.

■■■ - value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the second run.



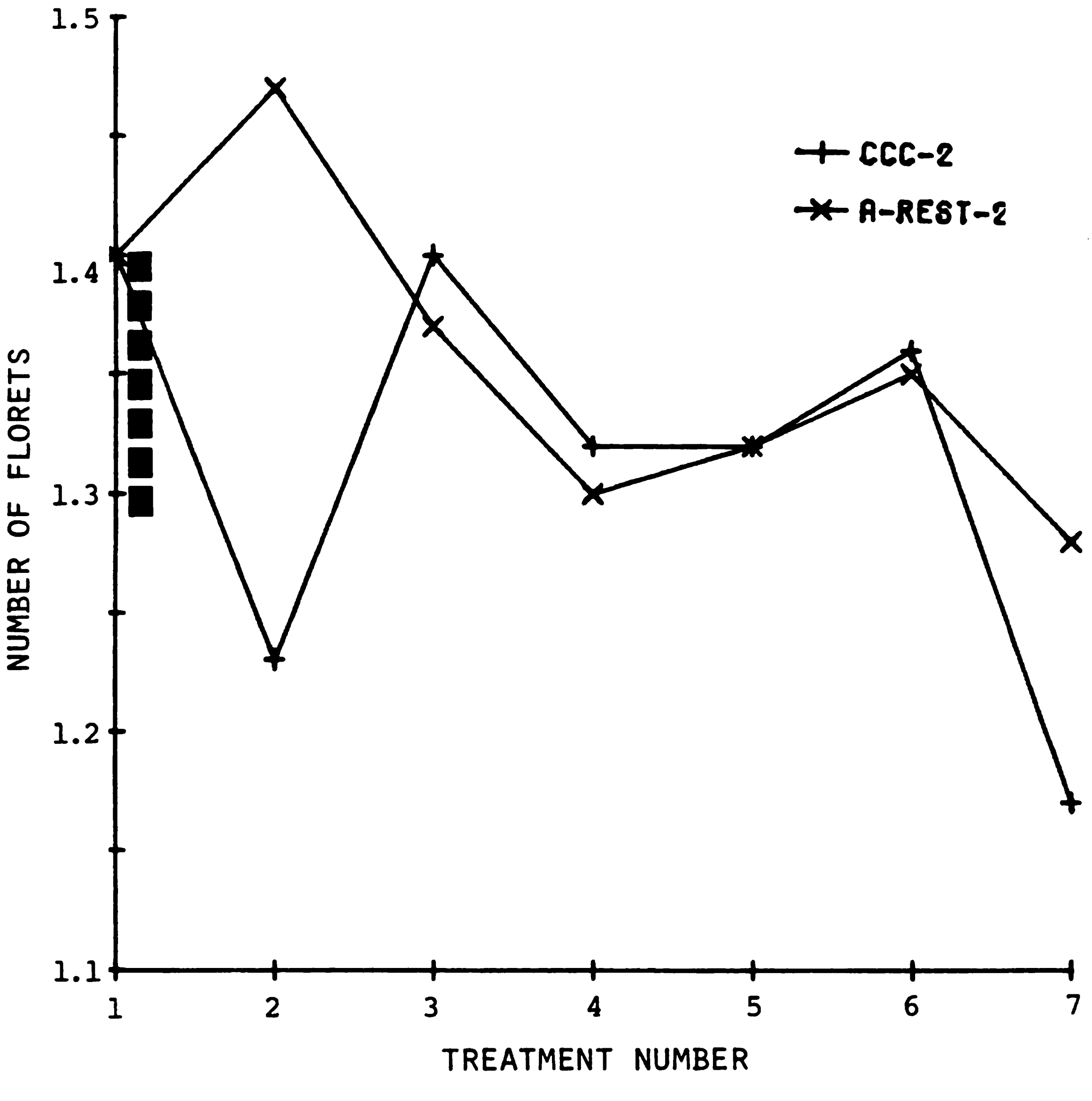
CCC-1
A-REST-1
CCC-2
A-REST-2
4.6
4.0
3.5
3.0
2.5
FLORET SIZE (CM)
1
2
3
4
5
6
7
TREATMENT NUMBER

Figure 13

Graph showing number of florets vs. time of application. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

Treatment number: 1 = control; 2 = application at 14 days after sown; 3 = 21 days; 4 = 28 days; 5 = 35 days; 6 = 42 days; 7 = 35 + 42 days.

■■■ - value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the second run.



CCC-2
A-REST-2
NUMBER OF FLORETS
1.5
1.4
1.3
1.2
1.1
1
2
3
4
5
6
7
TREATMENT NUMBER

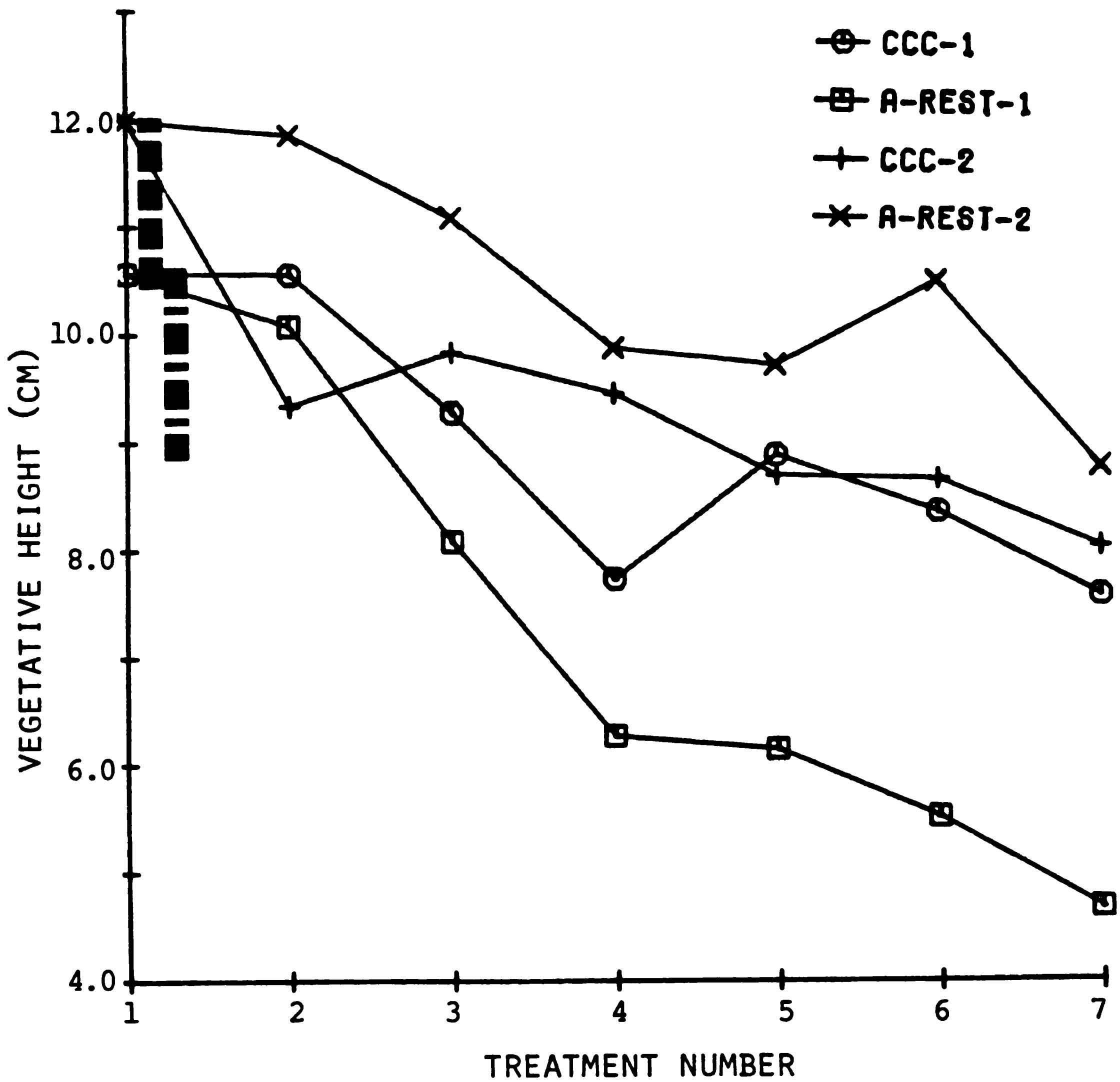
Figure 14

Graph showing vegetative height vs. time of application. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

Treatment number: 1 = control; 2 = application at 14 days after sown; 3 = 21 days; 4 = 28 days; 5 = 35 days; 6 = 42 days; 7 = 35 + 42 days.

- value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the first run.

- value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the second run.



CCC-1
A-REST-1
CCC-2
A-REST-2
12.0
10.0
8.0
6.0
4.0
VEGETATIVE HEIGHT (CM)
1
2
3
4
5
6
7
TREATMENT NUMBER

Figure 15

Graph showing total height vs. time of application. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

Treatment number: 1 = control; 2 = application at 14 days after sown; 3 = 21 days; 4 - 28 days; 5 = 35 days; 6 = 42 days; 7 = 35 + 42 days.

■▮■ - value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the first run.

■■■ - value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the second run.

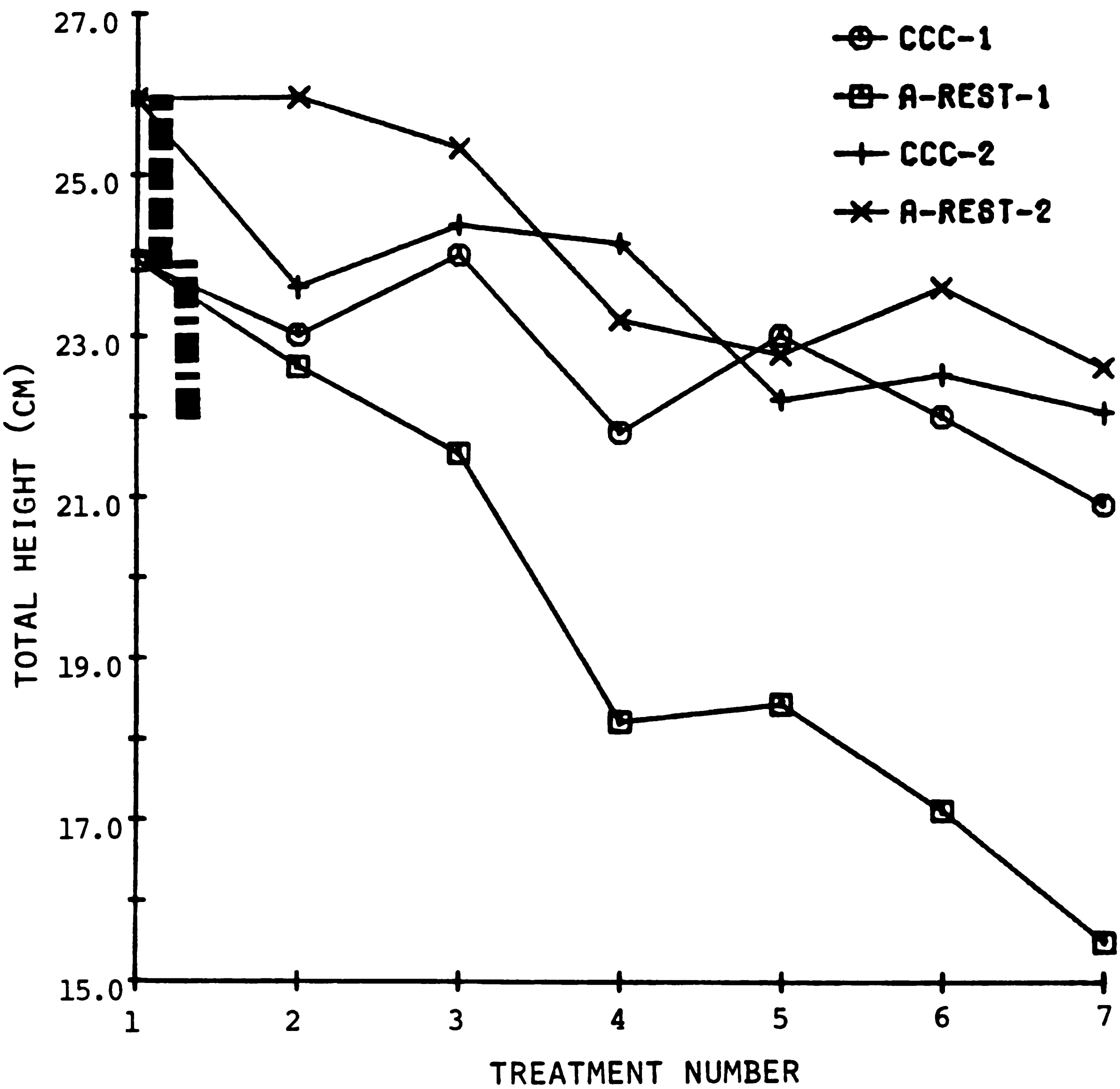

CCC-1
A-REST-1
CCC-2
A-REST-2
27.0
25.0
23.0
21.0
19.0
17.0
15.0
TOTAL HEIGHT (CM)
1
2
3
4
5
6
7
TREATMENT NUMBER

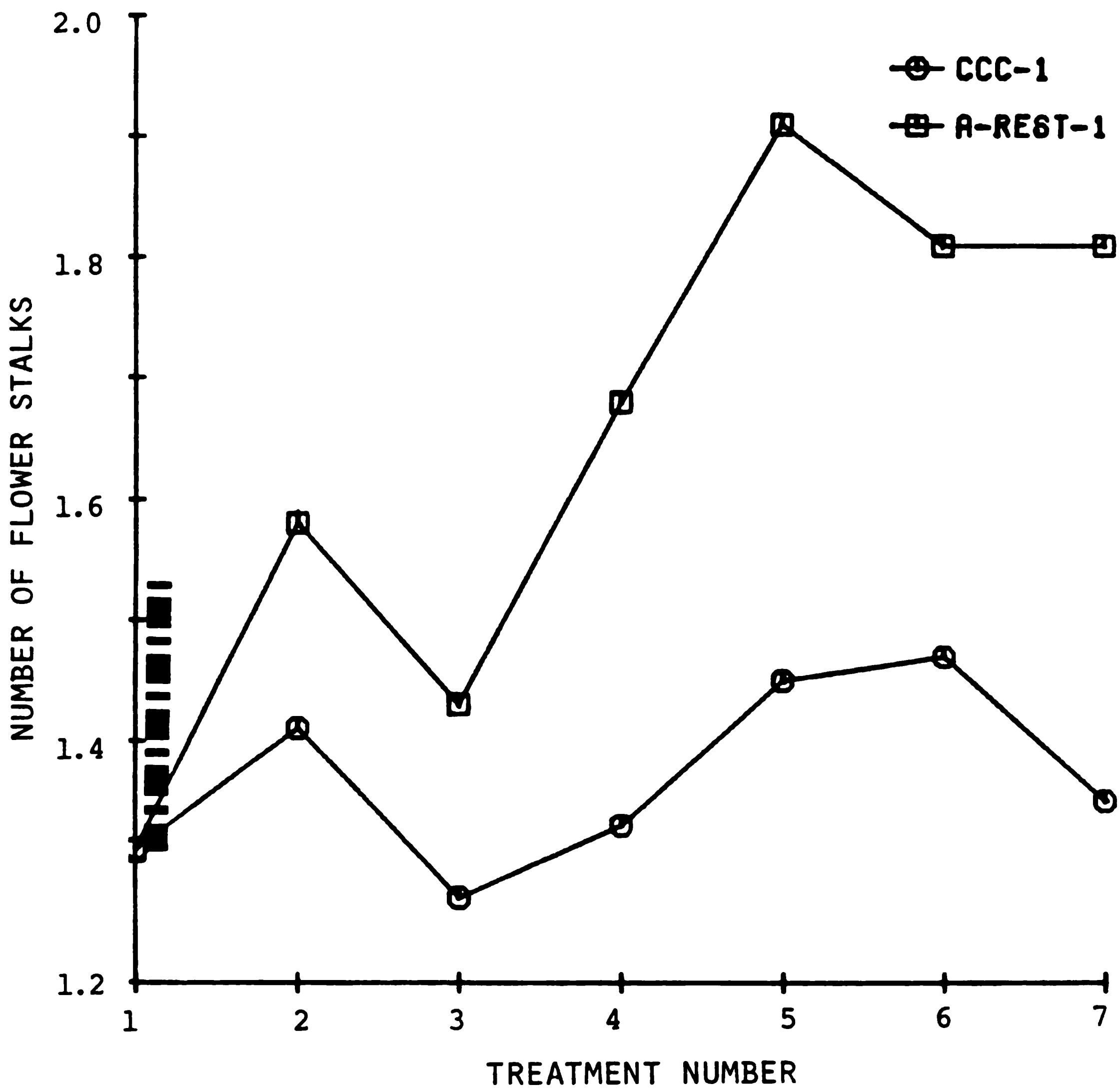
Figure 16

Graph showing number of flower stalks vs. time of application. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

Treatment number: 1 = control; 2 = application at 14 days after sown; 3 = 21 days; 4 = 28 days; 5 = 35 days; 6 = 42 days; 7 = 35 + 42 days.

- value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the first run.

- value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the second run.



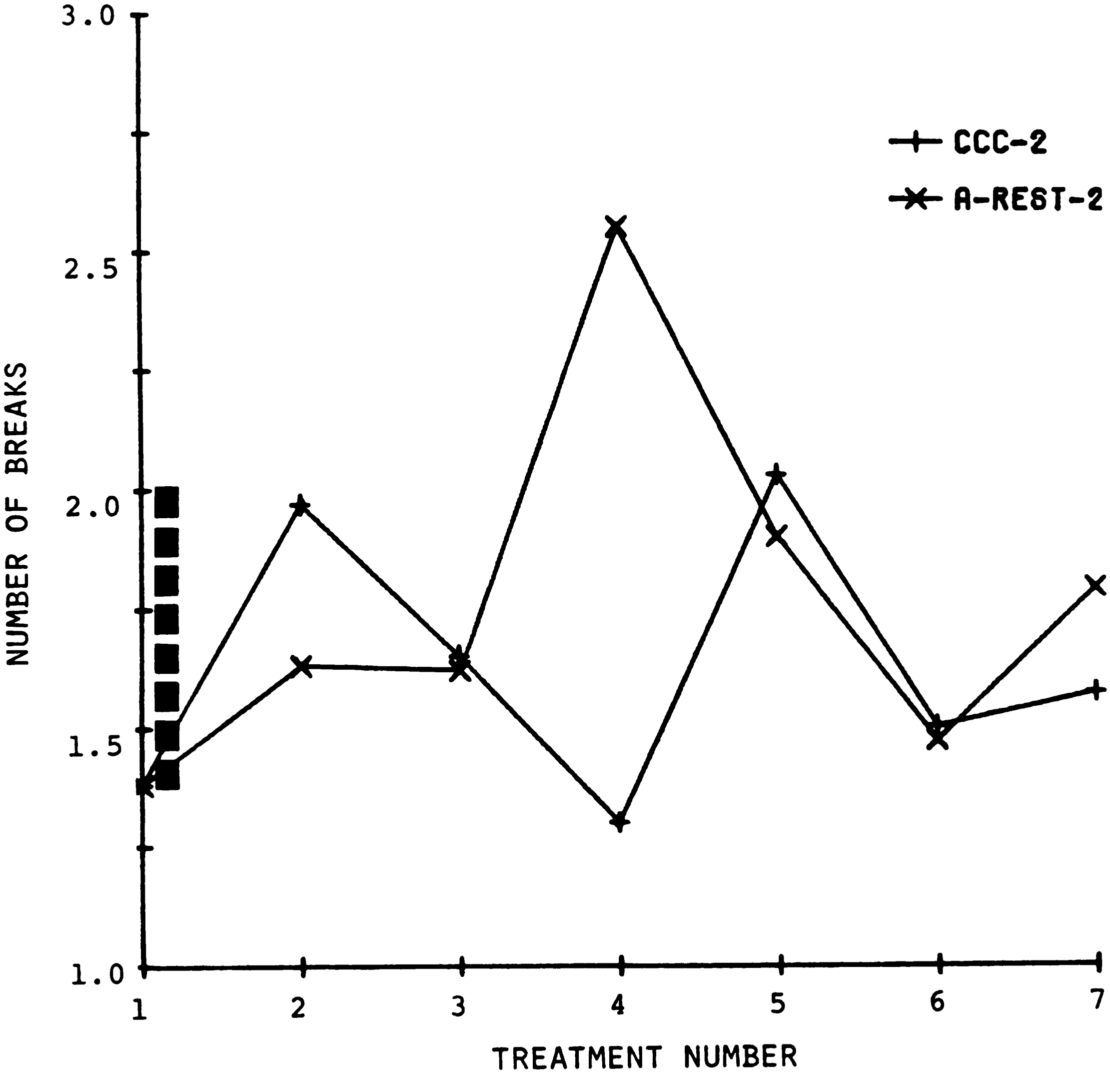
2.0
1.8
1.6
1.4
1.2
NUMBER OF FLOWER STALKS
CCC-1
A-REST-1
1
2
3
4
5
6
7
TREATMENT NUMBER

Figure 17

Graph showing number of breaks vs. time of application. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

Treatment number: 1 = control; 2 = application at 14 days after sown; 3 = 21 days; 4 = 28 days; 5 = 35 days; 6 = 42 days; 7 = 35 + 42 days.

■■■ - value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the second run.



3.0
2.5
2.0
1.5
1.0
NUMBER OF BREAKS
1
2
3
4
5
6
7
TREATMENT NUMBER
CCC-2
A-REST-2

Figure 18

Graph showing leaf diameter vs. time of application. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

Treatment number: 1 = control; 2 = application at 14 days after sown; 3 = 21 days; 4 = 28 days; 5 = 35 days; 6 = 42 days; 7 = 35 + 42 days.

- value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the first run.

- value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the second run.

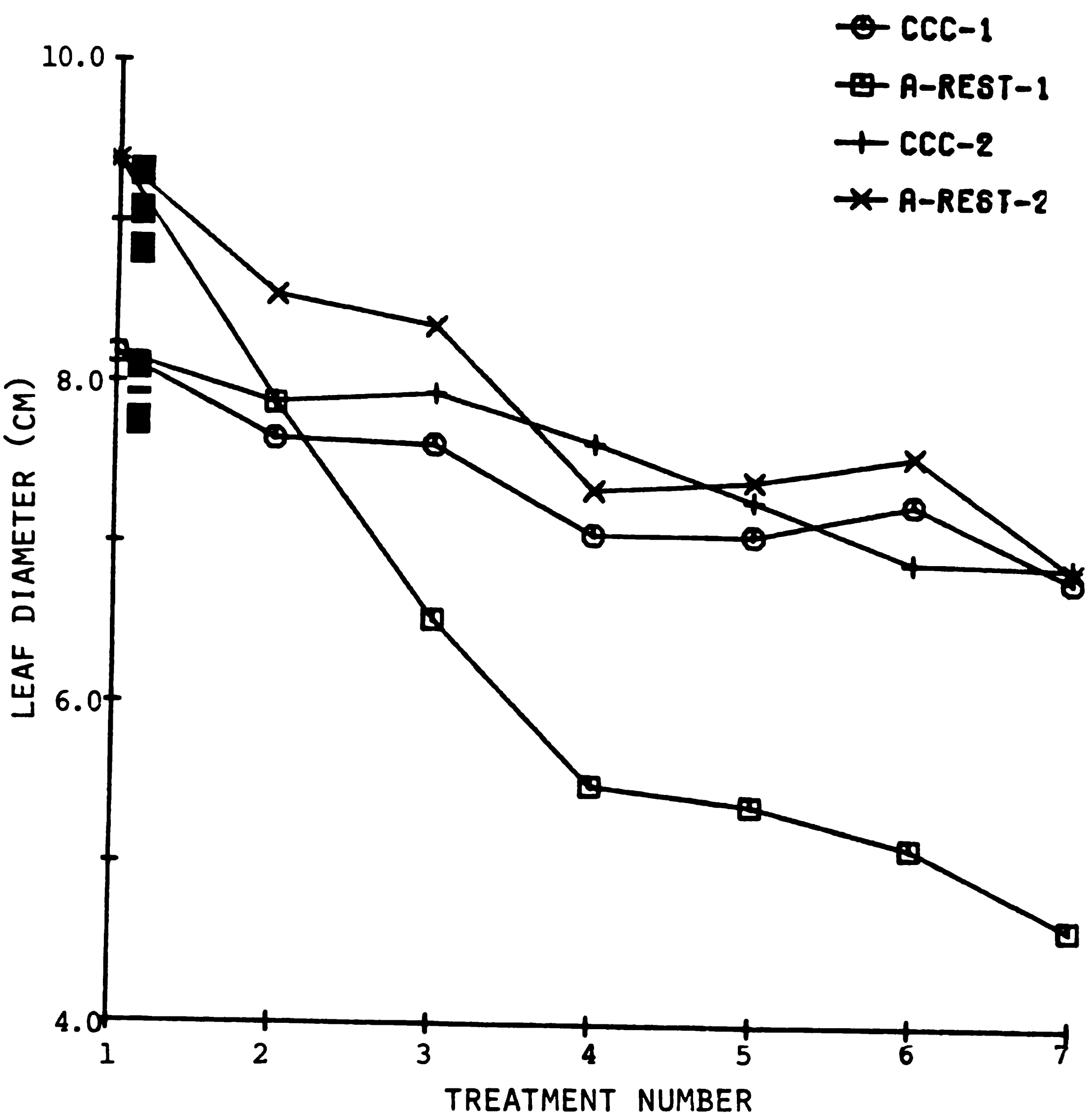

CCC-1
A-REST-1
CCC-2
A-REST-2
10.0
8.0
6.0
4.0
LEAF DIAMETER (CM)
1
2
3
4
5
6
7
TREATMENT NUMBER

Figure 19

Graph showing fresh weight vs. time of application. CCC-1 and A-Rest-1 are treatments for the first run, started on 2/23/78. CCC-2 and A-Rest-2 are treatments for the second run, started on 4/17/78.

Treatment nubmer: 1 - control; 2 = application at 14 days after sown; 3 = 21 days; 4 = 28 days; 5 = 35 days; 6 = 42 days; 7 = 35 + 42 days.

- value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the first run.

- value of LSD at 5% level for comparison of time of application treatments for each growth retardant, in the second run.

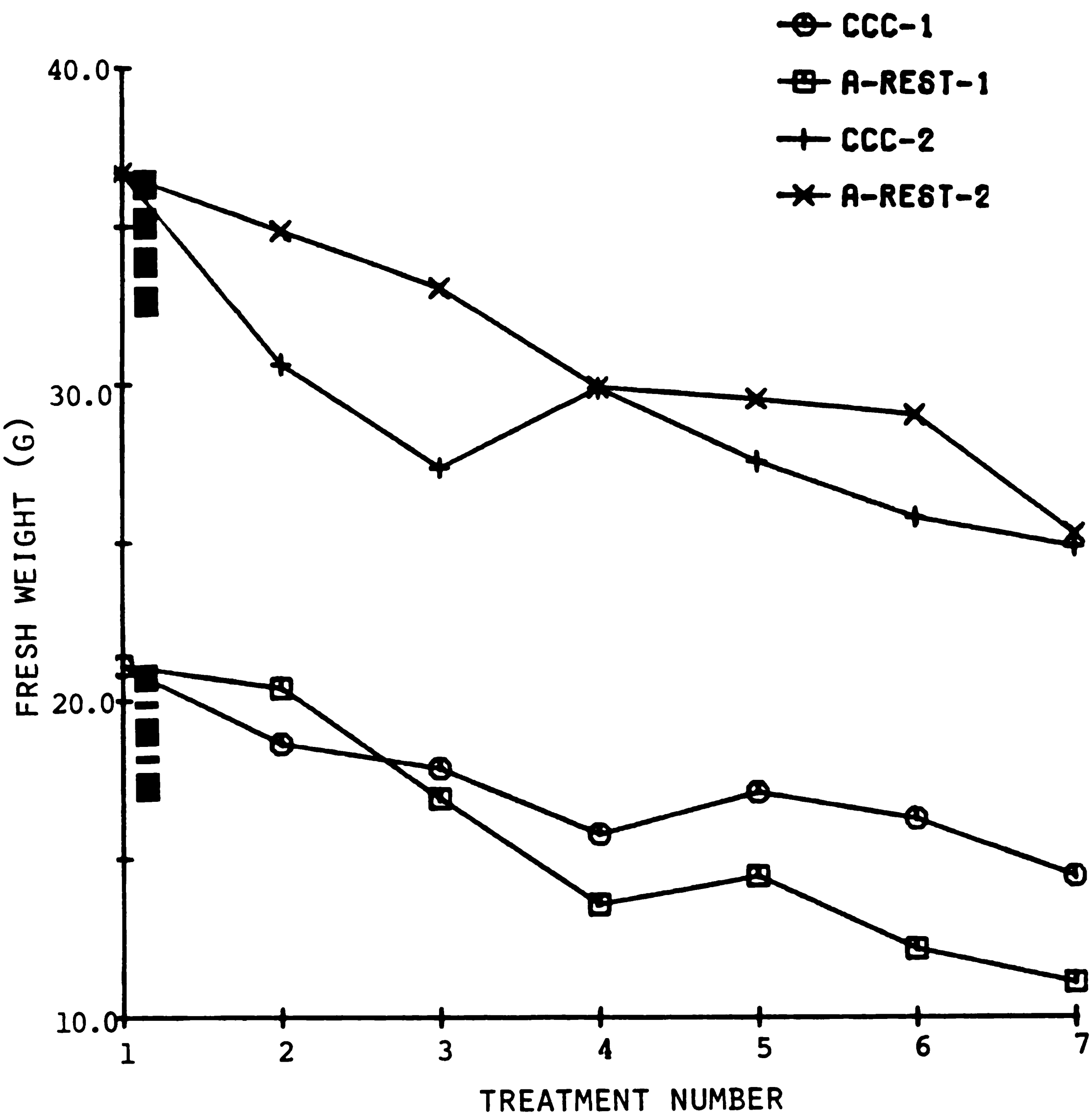

CCC-1
A-REST-1
CCC-2
A-REST-2
40.0
30.0
20.0
10.0
FRESH WEIGHT (G)
1
2
3
4
5
6
7
TREATMENT NUMBER

Figure 20

Comparison among time of application treatments.

Check = untreated; 14 = application at 14 days; 21 = application at 21 days; 28 = application at 28 days; 35 = application at 35 days; 35+42 = application at 35+42 days; 42 = application at 42 days after sowing. (Seeds sown on 2/23/78.)

a) Sprinter Scarlet plants treated with Chlormequat (CCC).

b) Sprinter Scarlet plants treated with Ancymidol (A-Rest).

c) Sprinter Salmon plants treated with Chlormequat (CCC).

d) Sprinter Salmon plants treated with Ancymidol (A-Rest).


JUNE 16
113 DAYS
SSC
CHECK
CCC
14
21
28
35
35-42
42

a


JUNE 16
113 DAYS
SSC
CHECK
AREST
14
21
28
35
35-42
42

b


JUNE 16
113 DAYS
SSA
CHECK
CCC
14
21
28
35
35-42
42

c


JUNE 16
113 DAYS
SSA
CHECK
AREST
14
21
28
35
35-42
42

d

RESULTS

Part C

Meristematic Studies

This work was done to observe if the early flowering due to growth retardants is achieved because of an earlier induction or because of an accelerated development of the flower sprout.

Table 7 shows the time from sowing to the observation of meristematic flower initiation and to the time of actual flowering. The results for CCC and A-Rest treatments for each time of application plus the control were recorded. Means separation was done only for the actual flowering results. All the time of application treatments for both growth retardants were significantly effective in reducing days to flower when compared with the control, but they did not differ among themselves.

The interval for initiation time showed on Table 7 was used because the samples were taken weekly and the initiation took place before the actual observation day and after the previous observation. Although the statistical analyses are absent, the trends of the data for flowering initiation are very close to the trends for actual flowering. The flowering initiation on the control occurred about seven days later than any of the growth retardants time of application treatments.

Figure 21 shows the different stages of the meristem development.

TABLE 7. Meristematic flower initiation and actual flowering data for time of application of CCC and A-Rest vs. control. Data were taken for Sprinter Scarlet plants, sown on 4/17/78. (The data are expressed in days after sowing.)

Time of Application (days after sowing)	CCC		Control		A-Rest	
	Initiation	Flower. (1)	Initiation	Flower. (1)	Initiation	Flower. (1)
—			56 - 63	100.6 a		
14	49 - 56	93.7 b			49 - 56	96.2 b
21	42 - 49	94.2 b			49 - 56	96.7 b
28	42 - 49	96.3 b			49 - 56	94.3 b
35	42 - 49	93.8 b			49 - 56	95.0 b
42	49 - 56	95.0 b			49 - 56	96.8 b
35 + 42	49 - 56	93.5 b			49 - 56	94.7 b

(1) Treatment means with the same letter are not significantly different by LSD at 5% level.

Figure 21

Morphological changes in the apical meristem during flower initiation of Sprinter Scarlet plants.

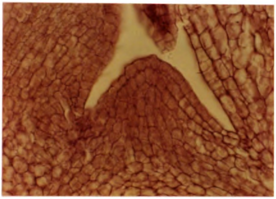
a) Vegetative stage (250 X).

b) First sign of differentiation; flattening of meristematic apex (250 X).

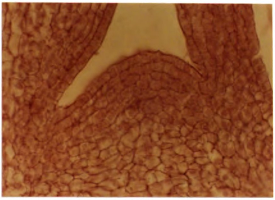
c) Meristematic differentiation to originate the inflorescence (250 X).

d) Inflorescence differentiated (50 X).

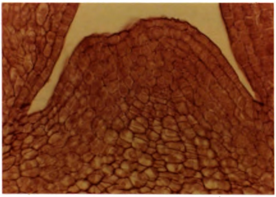
e) Differentiation of the inflorescence parts (50 X).



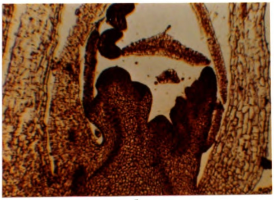
a



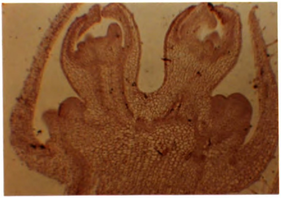
b



c



d



e

DISCUSSION

In all the experiments conducted the cultivars Sprinter Scarlet and Sprinter Salmon responded similarly to CCC and A-Rest treatments, although Sprinter Salmon appeared slightly more sensitive to growth retardants than Sprinter Scarlet. This verifies the results of Carlson (1976), but contrasts work of Payne (1969) and White (1970). The similarities in response may be because the tested cultivars are from the same developmental series (Sprinter). The slight differences between cultivars may be the results of the fact that lighter flower colors appear to flower earlier and at a shorter height (Craig, 1968).

No interaction was detected between spacing and growth retardant treatments. A denser spacing seemed to cause an increase in plant total height and decrease in the number of breaks. No difference was observed in days to flower, vegetative height and the other parameters. Although the plants in a pot-to-pot spacing are more difficult to grow and produce lower number of breaks than plants in a wider spacing, the pot-to-pot spacing should be recommended because of economical reasons. Problems with Botrytis or leggy plants, as reported by Rathmell (1971), were not observed under dense spacing.

Our work confirmed work by Holcomb and White (1968) and Carlson (1976) that seed geranium plants treated with CCC and A-Rest had different growth and flowering responses than non-treated plants. In an early sowing A-Rest seemed to be more effective than CCC. In a late sowing the two growth retardants acted almost in the same manner. It seems that A-Rest is more effective under low light conditions. Jansen (1973) concluded that CCC induces early flowering by "replacing a part of the necessary light summation for the flower induction. If A-Rest acts in the same manner, probably it has the characteristic to "replace" light more effectively than CCC; thus the greater efficiency in inducing flowering under low light conditions. When the available light increased A-Rest and CCC had almost the same effect on treated plants, as happened in the second run. The effect of A-Rest seemed to last longer than the effect of CCC in controlling plant growth, after transplanting to garden conditions as seen on Tables 3 and 6.

Growth retardant treated plants showed a decrease in: days to flower, floret size, number of florets, vegetative height, leaf diameter and fresh weight compared with control plants. However, the number of flower stalks and the number of breaks were greater on treated plants compared with control plants. Similar results were reported by Carlson (1976), although he observed that control plants produced higher number of flowers than treated plants. This difference may be because he considered the average of ten cultivars and number of flowers is very dependent on cultivars. Results on days to flower, plant height, number of breaks and fresh weight agree with the results reported by White (1970) and Semeniuk and Taylor (1970).

A single application of 35 days after sowing was as effective as any multiple application in decreasing days to flower. Similar results were obtained with CCC treatments by Jansen (1973). He worked with the cultivar Carefree "Crimson". Although the application time was not the same used in our experiment, he compared a single application with double application and the flowering time was not significantly different between these treatments, however both were significantly earlier than the control as observed in the present work. The decrease in number of florets was not significantly different on plants treated once and plants treated with multiple applications.

The main objectives in using growth retardants on seed geraniums are: decrease days to flower, control plant height and increase number of breaks. Considering these objectives and according to our results, three or four applications are little more effective than the double application. The single application at 35 days gave the same results as multiple applications regarding time to flower, but it was less effective in controlling height. Therefore a double application at 35 and 42 days after sowing should be used in order to be sure that the objectives will be met. Three and four applications showed almost the same results as single and double application in decreasing time to flower. The other parameters were over-emphasized by three or four applications. Plant height was severely checked with those treatments, under our experimental conditions. According to our results more than two applications were not only unnecessary but also decreased the commercial value of finished plants. These results were more critical in the early sown crop, than in the late sown crop. Although more than two applications did not give good responses in our experiments, there are some environmental conditions which cause excessive plant height when three or four applications can be used to control plant size more effectively (Heins *et al.*, 1978).

The above results led us to formulate the hypothesis that the mode of action of CCC and A-Rest on seed geraniums can be considered in two different manners: 1) effect on flowering time; 2) effect on plant growth. The effect on flowering time is probably related with the hypothesis formulated by Jansen (1973) by which the growth retardant "replaces" part of the necessary light summation for the flower release. The effect of growth retardants on plant growth is probably related with their effect to inhibit synthesis of gibberelin as reported by Lang (1970), thus reducing height and affecting other growth characteristics as fresh weight and leaf size.

Our results on the time of application experiments reinforce the above hypothesis; because, any time of growth retardant application gave the same effect in reducing flowering time, although the control of plant growth was only achieved when the application was done later than 28 days after sowing. As seen on Tables 4 and 5, all the treatments after 28 days were more efficient in controlling plant growth.

According to our results on the meristematic studies, it is apparent that growth retardants seem to cause early flowering due to early initiation. This result agrees with Jansen (1973). Since the flower initiation occurred between 42 and 63 days after sowing, the growth retardant application must be done before 42 days after sowing to induce early flowering.

A single application at 28 or 35 days appears to be satisfactory to decrease flowering time. But in order to achieve more accurate results regarding growth control, i.e. plant height, the double application at 35 and 42 days should be recommended. A single application at 42 days did not appear to be as effective as the double application at 35 and 42 days and single applications at 28 or 35 days in controlling plant growth.

Further investigation about the mechanism of flower induction of seed geraniums and the mode of action of growth retardants on decreasing flowering time, should be done in order to verify the hypothesis formulated based on this work.

SUMMARY

According to the results the growth retardant and the time of application, can be chosen from the following scheme, depending on the desired results.

Growth Retardant	Light Conditions	Overall Effect
A-Rest	low	Excessive
	high	Good
CCC	low	Good
	high	Good

Application Time[1] (days after sow.)	Days to Flower	Plant Height	Number of Breaks
28	Effective	Less effective	Effective
35	Effective	Effective	More effective
35 + 42	Effective	More effective	Less effective

[1]Any of the recommended application time gave good overall results. The above recommendation was based on slight variations observed in this present research.

LITERATURE CITED

LITERATURE CITED

Adams, R. W. 1978. Seed Geranium. Ohio Florists' Assn., Bulletin No. 579: 3-4.

Armitage, A. M., M. J. Tsujita and P. M. Harney. 1978. Effects of Cycocel and high-intensity lighting on flowering of seed-propagated geraniums. Journal of Horticulture Science 53: 147-149.

Carlson, W. H. 1974. Trials of A-Rest on vegetative geranium cuttings. Unpublished data.

Carlson, W. H. 1976. How growth retardants affect seed geraniums varieties. Michigan State University Ag. Expt. Station. Research Report No. 302: pp. 8.

Carlson, W. H. 1978. Personal communication. Michigan State University.

Carpenter, W. J. 1974. High intensity lighting in greenhouse. Michigan State University Ag. Expt. Station. Research Report No. 255: 10-11.

Carpenter, W. J., G. R. Beck and G. A. Anderson. 1974. High intensity supplementary lighting during rooting of herbaceous cuttings. The Michigan Florist: 10-13. March.

Carpenter, W. J. and W. H. Carlson. 1969. Supplemental lighting of 'Carefree' geranium. The Michigan Florist: 11 and 27. September.

Carpenter, W. J. and W. H. Carlson. 1970. The influence of growth regulators and temperature on flowering of seed-propagated geraniums. HortScience 5(3): 183-184.

Carpenter, W. J. and R. C. Rodriguez. 1971. Earlier flowering of geranium cv. 'Carefree Scarlet' by high intensity supplemental light treatment. HortScience 6(3): 206-207.

Craig, R. 1960. The effects of various cultural practices, temperature and photoperiod on the growth and maturity of *Pelargonium hortorum* seedlings. M.S. Thesis. The Pennsylvania State University. pp. 100.

Craig, R. 1968. Past, present and future of seedling geraniums. Penn. Flw. Grow. Bull. 204: 1-2 and 7. February.

Craig, R. 1971. Cytology, genetics and breeding. Geraniums. A Penn State Manual. Chapter 33: 315-346. Pennsylvania Flower Growers. University Park, Pennsylvania.

Craig, R. and D. E. Walker. 1961. What is in your future, commercial geranium from seeds. Penn State Geranium Clinic Manual: 84-92.

Craig, R. and D. E. Walker. 1963. The flowering of *Pelargonium hortorum* Bailey seedlings as affected by cumulative solar energy. Proc. Amer. Soc. Hort. Sci. 83: 772-776.

Crop Reporting Board. 1978. Floriculture crops — production area and sales, 1976 and 1977 intentions for 1978. E.S.C.S., U.S.D.A. Sp Cr 6 - 1: pp. 27.

Crossley, J. H. 1968. Warm vs. cool short days as preconditions for flowering of *Pelargonium domesticum* cultivars. Can. J. Plant Science 48: 211-212.

Ewart, L. L. 1978. Personal communication. Michigan State University.

Hackett, W. P. and J. Kister. 1974. Environmental factors affecting flowering in *Pelargonium domesticum* cultivars. J. Amer. Soc. Hort. Sci. 99(1): 15-17.

Hackett, W. P., J. Kister and A.T.Y. Tse. 1974. Flower induction of *Pelargonium domesticum* Bailey cv. 'Lavender Grand Slam' with exposure to low temperature and low light intensity. HortScience 9(1): 63-65.

Heins, R. D., H. E. Widmer and H. F. Wilkins. 1978. Growth regulators effective on floricultural crops. Minnesota State Florists' Bulletin: pp. 4. August.

Holcomb, J. and J. White. 1968. Cycocel for height control of fast-crop seedling geraniums. Penn. Flw. Grw. Bull. 203: 4-5.

Jansen, H. 1973. Forderung der Blutenbildung bei Fi - Pelargonien durch CCC. Z. Pflanzenphysiol. Bd. 70. S. 259-265.

Johansen, D. A. 1940. Plant Microtechnique. McGraw-Hill Book Company, Inc. New York and London: 126-154.

Konjoian, P. S. and H. K. Tayama. 1978. Production schedules for seed geraniums. Ohio Florists' Association Bull. 579: 1-2.

Lang, A. 1970. Gibberellins: structure and metabolism. Ann. Rev. Plant Physiol. 21: 537-570.

Larson, R. 1968. Influences of cultural procedures on growth and flowering: N.C. State research on seedling geraniums. Publ. Dept. Hort. Sci. N.C. State University 11: pp. 24.

Lindstron, R. S. 1967. Fl hybrid geraniums. The Mich. Florist 439: 12.

Mastarlez, J. N. 1967. Geraniums in 6 weeks. Penn. Flow. Growers Bulletin 193: 1-2 and 9. March.

Mastarlez, J. W. 1977. The Greenhouse Environment. John Willey and Sons. Chapter 9: 520-596.

Nilsen, J. H. 1975. Factors affecting flowering in 'Regal Pelargonium' (*Pelargonium* x *domesticum* Bailey). Acta Hort. 51: 299-309.

Norton, R. A. 1973. Stimulating earlier blooming of seed geraniums with high intensity lighting. Florists' Review 153: 25, 67-68.

Norton, R. A. 1975. Stimulating earlier flowering of seed propagated Fl hybrid geraniums with high intensity illumination and growth regulators. Unpublished data.

Payne, R. M. 1969. Effects of Cycocel treatment and direct seeding method on growth and flowering of seedling geraniums. Okla. State. Univ. Agr. Res. Prog. Rpt. P. 623: 1-19.

Pawlowski, H. E. and P. Schwandt. 1969. Gartenwelt 69: 473-476.

Plaut, Z., A. H. Halevy and E. Shmueli. 1964. The effect of growth retarding chemicals on growth and transpiration of bean plants grown under various irrigation regimes. Israel Jour. Agr. Res. 14: 153-158.

Poole, H. A. 1978. Growth Regulator Chart. Ohio Florists' Assn. Bulletin 580: pp. 3.

Poole, H. A. and H. K. Tayama. 1976. Extension slants the proper use of growth regulators. Ohio Florists' Assn. Bulletin 557: 7-10.

Post, K. 1949. Florist Crop Production and Marketing. Orange Judd Publishing Co., Inc. New York.

Post, K. 1942. Effects of day length and temperature on growth and flowering of some florists crops. Cornell Univ. Agr. Exp. Sta. Bull. 787: 1-70.

Rathmell, Jr., J. J. 1971. Geraniums from cuttings — growing and finishing flowering plants. Geraniums. A Penn State Manual. Chapter 13: 172-178. Pennsylvania Flower Growers. University Park, Pennsylvania.

Reed, D. D., D. C. Kiplinger and H. K. Tayama. 1976. The "growing on" of cuttings received from geranium stock plants given Florel treatments. Ohio Florists' Assn. Bulletin 555: 5.

Reilly, A. 1977. Geranium production for the coming year — notes and comments. Florists' Review 35: 84-85. December.

Semeniuk, P. and R. Taylor. 1970. Effects of growth retardants on growth of geranium seedlings and flowering. HortScience 5(5): 393-394.

Stinson, R. F. 1971. Environmental Factors — temperature, light, carbon dioxide. Geraniums. A Penn. State Manual. Chapter 9: 122-128. Penn. Flow. Grow. University Park, Pennsylvania.

Rerko, L. J. 1956. Studies on the effect of several environmental factors on the growth and flowering of the geranium (*Pelargonium* x *hortorum* Bailey). M.S. Thesis. Ohio State University.

Voigt, A. O. 1971. Statistics. Geranium. A Penn. State Manual. Chapter 1: 1-2. Penn. Flow. Grow. University Park, Pennsylvania.

White, J. W. 1970. Effects of Cycocel, moisture stress and pinching on growth and flowering of Fl hybrid geraniums (*Pelargonium* x *hortorum* Bailey). J. Amer. Soc. Hort. Sci. 95(5): 546-550.

White, J. W. and A. D. Wick. 1968. The response of seedling geraniums to selected fertility levels. Penn. Flow. Grow. Bull. 204: 4-6.

Wick, A. D. and J. W. White. 1968. The response of inbred seedling geraniums to selected water and fertility levels. Penn. Flow. Grow. Bull. 204: 3-4.

Wilkins, H. F. and R. E. Widmer. 1968. Cultural experiments with Fl geranium cultivars. Minn. Agr. Exp. Sta. Scientific Series Paper No. 6369: 1-8.